Mathematics that arises from collaborative gameplay in The Sims 3

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The following two publications (one solely and one jointly authored) include work drawn from the author's PhD research and were prepared and published whilst this thesis was being written. Both publications include elements related to preliminary findings of Case Study 1 (Marios and Christina's gameplay) of this research and are presented and discussed in more detail in Chapter 4 (Section 4.1), Chapter 5 and Chapter 6. In addition, both publications involve discussion of ideas which are discussed in more detail in Chapter 7 and in Chapter 8.

> Avraamidou, A. (2016). Instances of mathematical thinking through collaborative gameplay. In *Ninth Congress of the European Society for Research in Mathematics Education* (pp. 2453-2459). Prague: Charles University in Prague, Faculty of Education and ERME.
>
> Avraamidou, A., Monaghan, J. & Walker, A. (2015). Mathematics and Non-School Gameplay. In T. Lowrie, R. Jorgensen (Zevenbergen) (eds.), *Digital Games and Mathematics Learning, Mathematics Education in the Digital Era 4*, (pp. 11-34). New York: Springer.

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Abstract

Mathematics emerges and is used in out-of-school settings, such as workplace settings and everyday activities. An activity that many children enjoy doing in their everyday lives is playing digital games for entertainment. However, research exploring mathematics that emerges during children's gameplay in out-of-school settings is limited. This study aims to shed light to this field of research by exploring mathematics that arises in collaborative gameplay in *The Sims 3*, which is a real-life simulation commercial digital game that allows players to edit a domestic onscreen environment, in out-of-school settings and without a teacher's intervention.

Following a constructionist epistemology and a socio-cultural theoretical framework that views context as paramount, the research design of this study is 'embedded multiple case study', with activity being the unit of analysis. This study followed eight 8-12 year-old children who, in pairs, were asked to do two open tasks which are considered integral to this digital game's gameplay. First, they were asked to build, furnish and decorate a house without budget constraints and then a house for a selected Sims family with a budget constraint. The four groups' onscreen gameplay activity and talk was recorded using screen recording software; analysis focused on players' goal-directed actions and discourse during gameplay.

This study argues that players underwent an instrumental genesis during gameplay and that: i. mathematics that arose in players' gameplay activity was 'blended' with players' everyday prior understandings and the game's virtual artefacts and rules which they used as resources, ii. mathematical thinking in this game lies in players mathematicising relationships which are hidden in the game's virtual artefacts and become mobilised during gameplay, iii. the constrained gameplay influenced players' mathematical thinking as players experienced unexpected situations which required them to use their mathematical prior understandings and Mercer's exploratory type of talk.

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List of Abbreviations

3D – Three dimensional

A&E – Alexia and Eleni

CCA – Cultural conventions and artefacts

CUM – Cumulative Talk

DISP – Disputational Talk

ESL – English as a second language

EU – Everyday prior understandings

EXPL – Exploratory Talk

G&N – George and Nikos

GR – Game's restrictions

GU – Game prior understandings

GVA – Game's virtual artefacts

H1 / H2 – House 1 / House 2

M&C – Marios and Christina

M1 / M2 / M3 – Meeting 1 / Meeting 2 / Meeting 3

MA – Master (Postgraduate degree)

Mod(s) – Modification (in Minecraft digital game)

MS – Microsoft

MU – Mathematical prior understandings

NCTM - National Council of Teachers of Mathematics

PVA – Players' virtual artefacts

S&K – Stella and Katerina

SRS – Screen recording software

Part I: Setting the scene

Chapter 1 – Introduction

This thesis explores mathematics that arises in collaborative gameplay in *The Sims 3*, which is a commercial digital game (a game that was not designed for educational purposes) in out-of-school settings and without a teacher's intervention. It aims in making contributions to research related to mathematics and mathematical thinking that emerges in out-of-school settings by expanding adding knowledge on the way mathematics arises in the context of commercial digital games' gameplay in out-of-school settings. In addition, this thesis aims in informing research investigating children's gameplay of commercial digital games that allow them to set their own goals and to edit the onscreen environment. Such open-ended digital game-titles appear to be popular with gamers as they do well in the market of digital games (ESA, 2016). Lastly, the research design of this research aims to contribute to the field of research methodology being employed in dynamic and fluid contexts such as the gameplay of commercial digital games. The contributions of this thesis are discussed in the Conclusions of this thesis (Chapter 8, Section 8.2, p. 248). This chapter briefly introduces the motivation and rationale for this research in Section 1.1, followed by an overview of the research design and questions in Section 1.2 and, lastly, outlines the remaining chapters of this thesis in Section 1.3.

1.1 Motivation and rationale for this research

The digital game industry has developed rapidly during the last 20 years with digital games themselves being transformed so as to address the challenges of the 21st century (ESA, 2014). Recent surveys conducted in USA (ESA, 2016) and in sixteen countries of the European Union (ISFE, 2012) show that playing digital games is a popular activity in USA and European Union households. According to the results of Rideout, Foerh and Roberts' (2010) survey, the use of digital games by 8-18 year-old individuals in the USA, on a typical day, rose from 38% in 1999, to 52% in 2004 and 60% in 2009. Therefore, many children's daily activities involve digital gameplay. Being a frequent digital game player, I find myself agreeing with the 75% of the most frequent digital game players in the USA who "believe that playing videogames provides mental stimulation or education" (ESA, 2016, p.6). Yet, what kind of stimulation or education is provided in such games that were not designed for educational purposes? What kind of learning takes place during the activity of playing such digital games at home? Is there a relation to formal education?

Over the past decade several educational researchers have been investigating digital games and their effectiveness in relation to learning and formal education in a debate that is still ongoing (Steinkuehler & Squire, 2014). Although there are several researchers arguing that commercial games have potentials for learning and education (Gee, 2003; Prensky, 2001; Squire, 2008; Devlin, 2011) as it will be further discussed in Chapter 2 (Section 2.4.1, p.26), there are problems when integrating such games in formal education. One of the reasons such problems occur is because teachers integrate such digital games in their classroom, the goals and objectives of such commercial digital games as developed by their designers and the goals and objectives of students whilst playing such digital games might be different than their instructional goals and objectives (Squire, 2008; Greenstein, Panorkou & Seventko, 2016). As suggested by Squire (2008) and repeated by Young et al. (2012) meta-analysis there is still a lack of understanding and a lack of research investigating what players do and think in the activity of playing commercial digital games that were not designed for educational purposes. In other words, before integrating into classrooms digital games that were not primarily designed to be used in educational settings, more research is required to inform this field and shed light to educational researchers' understanding of the kind of actions and thinking stimulated when players play such commercial digital games in out-of-school settings.

Responding to the above research recommendations, this research focuses on mathematics and mathematical thinking because there is limited research investigating mathematics that emerges in gameplay of a commercial digital game in out-of-school settings and without a teachers' intervention. The European Commission (2011) sets mathematical competence as one of the key competencies a 21st century citizen should master, referring to individuals' ability to apply mathematical thinking in solving problems that can occur in real life activities. Real life activities are usually set in out-of-school settings. Surprisingly, there is, to my knowledge, no research that investigated mathematics and mathematical thinking in the context of commercial digital games, in out-of-school settings, apart from my previous research which was conducted for my master (MA) dissertation (Avraamidou, 2007).

However, several researchers have explored mathematics used in other out-of-school settings such as in the workplace (Noss, Pozzi & Hoyles, 1998; Magajna & Monaghan, 2003, Triantafillou & Potari, 2010), in buy-sell activities set in the streets and in activities set in daily life (Nunes, Schliemann & Carraher, 1993; Saxe, 1991) and in supermarket shopping (Lave, 1988). The results of the above research argue that mathematics does emerge and is used in such settings but it is not formal mathematics. Rather, it is 'street mathematics', 'supermarket mathematics', and so on. In addition, they argue that in such settings, mathematics is inextricably linked to the context (Maganjna & Monaghan, 2003). Nonetheless, in most of the above research participants were mainly adults and practitioners and in research where children were participating this was in buy-sell activities, mainly in socio-cultural contexts where it was common for children to engage in such practices to earn money (Saxe, 1991). Considering that, today, a popular activity in children's everyday life is playing digital games (ESA, 2016), the question arises: What sort of mathematics (if any) might emerge, is developed and is applied during gameplay? This thesis' research questions and a brief overview of the research design of this research are presented next.

1.2 Research questions and overview of research design

The aim of this study is to explore mathematics and mathematical thinking that arises in the collaborative gameplay of *The Sims 3* digital game. This particular game was not randomly selected. As it will be justified in more detail in Chapter 2 (Section 2.4.4.2, p.38), this game is a real-life, simulation, commercial digital game that allows players to edit the onscreen environment, set their own goals and proceed with their gameplay in an open-ended way. The general research question that drives this study is:

How does players' mathematical thinking emerge and/or is affected while being engaged in the collaborative activity of building virtual houses in The Sims 3 digital game, in out-of-school settings?

In order to answer the above general question, I address the following research sub-questions:

1. What potential is there for mathematical thinking in *The Sims 3* as a game?

2. How does players' mathematical thinking emerge and how is it influenced when players engage in a less constrained and in a constrained gameplay?

3. How do players collaborate during a less constrained and during a constrained gameplay?

4. How do players' goal-directed actions emerge during *The Sims 3* gameplay?

Following a constructionist epistemology and bringing together socio-cultural theoretical ideas that perceive context as paramount and learning as a mediated activity, I asked players-participants of this research to build virtual houses in *The Sims 3* digital game in out-of-school settings. The methodology employed for this research was an embedded multiple-case study (Yin, 2009). In particular, players played this game in groups of two, whereas each group was a case study and all four groups were perceived as an embedded multiple-case study, allowing for comparisons across the four cases. Players were asked to build two[1] virtual houses in *The Sims 3* digital game; a virtual house in a mode of *The Sims 3* game that has fewer constraints and then a virtual house in a mode of *The Sims 3* game that has more constraints. Their gameplay was recorded using screen recording software that captured their onscreen activity and their corresponding talk as they were playing this game on my laptop. Their talk during their gameplay and descriptions of their gameplay were transcribed and analysed. The unit of analysis of this research was players' goal-directed actions and talk which were constituents of their activity. I

[1] Initially the design of this research included a third house which involved players editing a scenario-based virtual house in *The Sims* 3. Although all groups went through the activity of editing this third house, their gameplay activity for this house is not reported in this thesis (see Chapter 3, Section 3.3.5, p.60).

analysed the characteristics, emergence and processing of each group's goal-directed actions and talk during gameplay, using open-codes (*à la* Strauss & Corbin, 1998), an adaptation of Saxe's (1991) model of emergent goals and Mercer's (2010) types of talk. The methodology, methods of data collection and the stages of analysis of this research are illustrated in more detail in Chapter 3 (Sections 3.3, 3.4 and 3.5, pp. 57-70).

1.3 Thesis organisation and outline

The main content of this thesis is organised in three parts; Part I: Setting the scene, Part II: Results and Findings and Part III: Discussion of findings and Conclusions. Below is a brief outline of the chapters included in those three parts.

Part I: Setting the scene. This part sets the scene by introducing the research's motivation, rationale and content in *Chapter 1 – Introduction* (p. 3), providing the theoretical background related of the key concepts involved in this thesis in *Chapter 2 – Theoretical background of key concepts* (p. 9) and describing and justifying the research design of this research in *Chapter 3 – Research Design* (p. 49).

Part II: Results and Findings. This part presents results and findings that derived from the analysis of this research's data, related to the research questions of this research. *Chapter 4 – Description of the four cases* (p. 89) introduces the four cases and provides a description of participants' gameplay. *Chapter 5 – Gameplay, goals, actions and talk* (p. 121) illustrates results that occurred during the first four stages of analysis of this research, providing a more in-depth analysis of players' gameplay. *Chapter 6 – Mathematics related episodes of interest* (p. 157) focuses on mathematics related elements of players' gameplay and illustrates, in detail, respective episodes of interest of players' gameplay.

Part III: Discussion of Findings and Conclusions. The part discusses key results and findings that were presented in Part II. *Chapter 7 – Discussion* (p. 205) addresses the research questions and discusses certain findings that emerged from the analysis of the data. Chapter 8 – Conclusion (p. 243) provides an overview of the key findings of this research and discusses the contributions, implications, limitations and further research recommendations of this research.

Chapter 2 – Theoretical background of key concepts

The research questions that were presented in the Introduction chapter include concepts which are important to review and clarify in this chapter. Guided by the general research question of this research, I initially conducted a review of literature using the keyword terms "mathematics and/or mathematical thinking", "digital or video games" and "out-of-school settings or (-)classroom" in four databases: ScienceDirect, Education Research Complete (Ebsco), Eric and IngendaConnect. My initial search revealed that there were a limited number of research publications that reported on mathematics and digital games and, apart from my MA research conference publication (Avraamidou & Monaghan, 2009), there was not – to my knowledge – any other publication up to that time (2010) where researchers conducted research regarding mathematics in digital gameplay in out-of-school settings. This led me to extend my search, using combinations of keywords that emerged from eight elements that Ihighlighted in the general research question: *mathematical thinking, emerge*, *engaged*, *collaborative, gameplay*, *activity*, *digital game* and *out-of-school settings*. These elements involve areas of research related to: i. *Mathematical thinking, ii. Mathematics in out-of-school settings – Goals, actions and emergent goals, iii. Tool–mediated activity and resources* and iv. *Digital games, gameplay and engagement*. These four research areas are reviewed in this chapter, in order to provide the reader with the theoretical background of the key concepts of this thesis. Nonetheless, a more detailed discussion of the way those concepts have informed the theoretical perspective of the research design of this research will be provided in Chapter 3 (See Section 3.2, p.52 and Section 3.5.2, p.71).

First, in Section 2.1 I review literature related to mathematical thinking and mathematical meanings. Then in Section 2.2 I outline research that explores mathematics in out-of-school settings because it informs the theoretical background of this research which is conducted in out-of-school settings. Next, in Section 2.3, I turn to research and theories related to tool-mediated activity and resources because participants' activity in my research is a tool-mediated activity. Since this research involves a digital game, I provide a review of the literature related to digital games, gameplay and engagement in Section 2.4. In Section 2.5 I return to mathematical thinking and provide an operational definition of the term as used in this thesis and lastly, in Section 2.6 I briefly summarise this chapter, justifying and outlining this thesis' research questions.

2.1 Mathematical thinking

The European Commission recommends mathematical competence as one of the eight key competences a citizen should develop for lifelong learning by being able to "to pose and solve mathematical questions, and to apply mathematical thinking to solve real life problems" (European Commission, 2011, p.8). As Burton (1984, p.36) states "An idea, an observation, a happening – any event can provide stimulus to begin thinking" (Burton, 1984, p. 36). But how is that type of thinking considered as *mathematical* thinking? Reviewing literature related to mathematical thinking, it appears that this is a complex area of scholarship as there are several ways in which the term is being used and referred to (see Argyle, 2012). Mathematical thinking is sometimes viewed as an end product (content) of students' justifications (Russell, 1999) whereas most of the time, it is viewed as a process or set of processes containing one or more mental activities that are related to mathematics (Mason, Burton & Stacey, 1982; Harel, Selden & Selden, 2006; Schoenfeld, 1992). Such mental mathematics related activities include specializing, conjecturing, generalizing, convincing, abstracting, visualizing, representing, modelling, inducing, deducing, formalizing, classifying, analysing and proving (Schoenfeld, 1992; Mason, Burton & Stacey, 1982; Burton, 1984; Lane & Harkness, 2012). Of course the list of the mental math-related activities can expand even more, depending on one's conceptualization of what mathematics and what math-related activity is.

Mathematical thinking is often associated with problem-solving (National Council of Teachers of Mathematics - NCTM, 2000; Schoenfeld, 1992). Considering the mental act of problem-solving, in respect to Harel's (2008a) view of mathematics as ways of understanding and ways of thinking, the solution to a problem is the product of that mental act of problem solving and it is the individual's way of understanding, whereas the problem solving approach is the characteristic of that way of understanding, which reveals the way of thinking of the individual (Harel, 2008b).

Several authors provided frameworks in respect to problem solving techniques, strategies, approaches and so on (i.e. Schoenfeld, 1992; Polya, 1945; Mason, Burton & Stacey, 1982). In his book *"How to solve it*" Polya (1945) suggested a framework for problem-solving involving four phases that an individual goes through in order to solve the problem; *a. understand the problem, b. devise a plan, c. carry out the plan* and *d. look back*.

Building on Polya's four phases of problem-solving, forty years later, in their book, "*Thinking mathematically",* Mason, Burton and Stacey's (1985) referred to three phases of "tackling a question" (p.26): *entry, attack and review* phases. During the entry phase, when an individual is faced with a problem (in their book the examples were mathematical problems articulated in a way that can be found in school textbooks), s/he should be able to identify the problem and what it is really about "by absorbing the information given and by finding out what the question is really asking" (p.29). Then an attack phase of thinking follows in which the individual is processing the issue in order to solve it. During this phase, Mason, Burton and Stacey (1985), describe four processes that underlie mathematical thinking and are central to mathematical activity; *specializing, conjecturing, generalizing and convincing (justifying)*. According to them, when the individual is trying to understand and solve the issue, starting in the *entry* phase, s/he can examine particular examples acting on – most of the time – specific and concrete elements, so as to explore the meaning of the problem and get a sense of what is going on, in a more inductive way of thinking. Such a process is for Mason, Burton and Stacey (1985) a process of *specializing*. Then, s/he enters the process of examining those examples more deeply, and might get a sense of an underlying pattern on which s/he is making a conjecture; "… a statement which appears reasonable, but whose truth has not been established" (Mason, Burton & Stacey, 1982, p. 63). Then, s/he articulates conjectures of the identified relationships and connections between the several elements being examined during the specialization process while making generalizations (generalizing) and can reorganize and modify those conjectures by specializing on even more the data of the issue and generalizing conjectures. As a final process of the *attack* phase, when the individual appreciates that a solution is found, s/he explores why that solution is the suitable and tries to explain why, in order to convince him/herself and others (convincing/justifying). Mason, Burton and Stacey (1985, p. 47) refer to the *review* phase as being the phase in which the individual will: i. “CHECK the resolution”, ii. “REFLECT on the key ideas and moments in the resolution” and iii. “EXTEND the result to a wider context”. If a solution is not found, the individual goes back and tries specializing-generalizing-conjecturing until a suitable solution is found or s/he abandons the issue. Mason, Burton and Stacey (1985) refer to the “essence of mathematical thinking” (p. 23) as being the whole process of entry-attack-review phases and specializing-conjecturing-generalizing-convincing processes described above.

Tall (2002, p.20) refers to both Polya’s four phases and Mason, Burton and Stacey (1985) entry-attack-review phases as elementary mathematical thinking that are being used by younger children when dealing with open-ended problems stating that “[w]hat is entirely absent is the notion of formal definitions and the logic of formal deductions from those definitions” and the notion of proof which are important for advanced mathematical thinking. Yet, advanced mathematical thinking as a term is, according to Selden and Selden (2005), ambiguous, as it is not clear whether *advanced* (and subsequently, *elementary*) refers to thinking or mathematics or both.

Apart from the connection to problem-solving, mathematical thinking is sometimes being used the same way as mathematical reasoning in literature. For example, NCTM (2009, p.4) suggests that mathematical reasoning “often begins with explorations, conjectures” before resulting to convincing and proving, similarly to Mason, Burton and Stacey’s (1985) reference to mathematical thinking processes. In addition, Polya (1954) divides reasoning in: demonstrative reasoning and plausible reasoning. “The result of the mathematician’s creative work is demonstrative reasoning, a proof; but the proof is discovered by plausible reasoning, by guessing mathematics” (Polya, 1954, p. vi). Polya (1954) refers to plausible reasoning as the kind of reasoning individuals do in their everyday activities and it is through such reasoning that they learn more about the world around them, whereas demonstrative reasoning does not produce new knowledge; rather demonstrative reasoning verifies existing knowledge. Plausible reasoning usually involves inductive reasoning (Burton, 1984), guesses (Lakatos, 1976) and inferences (Otten, Herbel-Eisenmann, & Males, 2010).

However, most of the definitions and description of mathematical thinking that were presented in this section perceive mathematics in the form of the formal kind of mathematics that is being taught in schools. Most of the examples given by those authors in order to describe i.e. the phases of problem-solving (Polya, 1945) or the three phases of thinking mathematically (Mason, Burton & Stacey, 1982) are problems and questions that involve symbolic representations of mathematics taught in schools. However, is mathematical thinking only being developed within a classroom and via textbook-like problems and activities? An operational definition of the way mathematical thinking is perceived in this thesis will be given in Section 2.5 (p.43). Now, I will shift my focus to research that explores mathematics that is used (and sometimes occurs) in out-of-school settings.

2.2 Mathematics in out-of-school settings

The activity of playing a digital game is a fluid activity that is often related to entertainment (Squire, 2004) and is an activity that both adults and children enjoy doing in their leisure time (ESA, 2016). As suggested by Avraamidou, Monaghan and Walker (2015) and Bourgonjon et al. (2010) there can be possible changes to gameplay of such digital games when they are moved from leisure to classroom, due to the tensions between the kind of mathematics that emerges in such gameplay and the mathematics that is involved in the curriculum of a school. Given that this research explores mathematics and mathematical thinking in an activity that is not set in school settings, it is important to understand the way mathematics emerges in such fluid settings, where teaching and learning mathematics is not of primary importance and where mathematics and mathematical thinking is not 'privileged' in mathematics found in textbooks (Wertsch, 1998) and is not studied and used by employees and other practitioners in a school-like way with school-like tasks and activities (Ruthven, Hennessy & Deaney, 2008). Thus, it is important to review literature relevant to mathematics in out-of-school settings.

Over the past three decades, there have been several researchers exploring mathematics in out-of-school settings in an attempt to – mainly – explore the transfer of mathematics being taught in schools (school settings) to real life – everyday and work activities (out-of-school settings) – of individuals (Monaghan, 2016b). One of the first to explore mathematics in individuals' everyday activities and, in particular, within the setting of a supermarket, Lave (1988) found out that when individuals made arithmetical calculations in order to select best-buy options within supermarket settings (informally) and then were asked to do the same calculations within a classroom (formally), 'supermarket calculations' outperformed 'school calculations'. Lave's (1988) finding was something that Nunes, Carraher and Schliemann (1993) also observed when studying mathematics used by children while selling goods in the streets of Brazil which they named as 'street mathematics'. Nunes et al. (1993) compared the 'street mathematics' with children's performance when using similar mathematics (calculations) in school and in the streets and found that 'street mathematics' outperformed 'school mathematics'.

Nonetheless, in the '*situated cognition*[2]' theory that Lave (1988) developed in order to support her data she made a distinction of the mathematics that individuals did in the supermarket setting and the mathematics that the individuals did in school because school and supermarket (in that case), for Lave (1988) were two different social practices in two different contexts and, thus she claims, could not have affected each other. However, Noss and Hoyles (1996a) critiqued Lave's conclusions because as they highlighted, the calculations that individuals did in the supermarket setting were not – for the shoppers – identical to the calculations they were asked to do in the school setting, and "when shoppers do use mathematics in the supermarket, it is supermarket mathematics, a mathematics made possible through the resources of the supermarket" and this is something I will return to towards the end of this section. About the same time as Lave (1988) communicated her findings, Saxe (1991), in a non-Western research of investigating the practice of children selling candies in the streets of Brazil found that the mathematics that children use in their practice and the mathematics being taught in schools influence each other. This dichotomy of formal and informal mathematics was something that initiated research focusing on informal mathematics (Noss & Hoyles, 1996a) and mathematics in out-of-school settings and in particular in workplace settings.

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[2] Lave's (1988) 'situated cognition' theory argues that everything a person knows is inseparable from what s/he does and bounded within the context s/he is in (cultural, social, physical).

2.2.1 Mathematics in workplace settings

Several researchers investigated mathematics' use in workplace by observing practitioners in workplace settings. For example, Scribner (1986) reported that milk-processing employees, and in particular the ones who were responsible for assembling different quantities and products in cases in order to fill in orders used complex strategies, that were not school-alike algorithms, in order to effectively assemble the orders in a minimum number of required moves. Millroy (1992) investigated carpenters' everyday work and found that there are several mathematical ideas embedded within the practice of carpenters, such as symmetry and proportional reasoning. Similarly, in a more recent research, the practice of the Maley Songket weavers was explored and mathematical concepts such as transformations, geometrical concepts and patterns and scaling were identified during the weavers' everyday thinking (Embong, Aziz, Wahab & Maidinsah, 2010). Noss, Hoyles and Pozzi in a series of publications (Pozzi, Noss & Hoyles, 1998; Hoyles, Noss & Pozzi, 2001; Noss, Hoyles & Pozzi, 2002) report that nurses' conceptions were both situated and abstracted within their practice as they drew on both their mathematical knowledge and their professional knowledge in order to perform tasks in their practice, such as drug administration and fluid balance monitoring. Furthermore, Nunes, Carraher and Schliemann (1993) reported on the development of fishermen's proportional reasoning in everyday and fishing practices, Magajna and Monaghan (2003) explored technicians' mathematical thinking and concepts of volume in the context of manufacturing practice and Triantafillou and Potari (2010) reported on the mathematical meanings that technicians in a telecommunication organizations constructed related to the concepts of "place value, spatial and algebraic relations" which were emerged within processes related to "reading and interpreting data, performing calculations, measuring and applying problem-solving strategies" (Triantafillou & Potari, 2010, p.291).

The majority of the above body of research identified and explored mathematics and mathematical understandings that practitioners bring and use in their work practice and reported findings that provide valuable insights for mathematics education. A first common finding of the research outlined above is that mathematics *can* be observed in several activities within workplace practices and a second common finding is that even though there is visible mathematics identified at once in such practices, in the sense of *"*easily recognisable mathematical operations" (Pozzi, Noss & Hoyles, 1998, p.107), there is in fact a more complicated nature of mathematics used in such practices as it is embedded and contextualised in the particular practice (Triantafillou & Potari, 2010) and the kind of mathematics being used is not school-like mathematics (Magajna & Monaghan, 2003). For example, fishermen's proportional reasoning developed in everyday activities and fishing practice, as reported by Nunes et al. (1993) research, was bounded within the context of the fishing activity setting and made sense within that practice. Furthermore, Noss, Hoyles and Pozzi (2001; 2002) who observed nurses during their practice referred to nurse's displaying situated abstraction as they reported that the nurses had "abstracted knowledge from engaging in their work, but this knowledge remained to some extent situated" (p.226). Similarly, Maganja and Monaghan (2003) found that practitioners' "mathematical reasoning and problem solving was inextricably linked to their working context" (p.120) and "to the contextual resources" (p.112). They also concluded that: "Mathematics in a workplace is not just bits of school-like mathematical reasoning found in workplace" (p.120). The practitioners in their study apart from understanding mathematical concepts, they: "must be able to relate any mathematics they use to their work context and to the complexity of the activity structure" (p.121). Furthermore, a third common element in the findings of the above researches which will be thoroughly discussed in Section 2.3.3 (p.20). is the key role that the at hand tools and resources – physical and mental – played in constructing practitioners mathematical meanings and strategies in their workplace practice activities (Hoyles, Noss, & Pozzi, 2001).

Lastly, most of the workplace mathematics research reported on practitioners' mathematics concepts, understandings, reasoning and problem-solving strategies that were practice-linked, were emerged during their practice and were in some cases, invisible (Noss & Hoyles, 1996a). However, Noss, Hoyles and Pozzi (1998, p.108) reported that mathematics that nurses used in practice became visible in *'breakdown moments'* of unexpected situations during their practice. In such unexpected situations, “activities which would ordinarily be characterised as unproblematic, routine actions were replaced by conflict, disagreement and doubt, resulting in more spontaneous explanations which made nurses’ reasoning and problem–solving more evident” (p.108). In such *‘breakdown moments’* in practice, practitioners need to alter plans and proceed with actions that are different than the routine actions they usually perform in their practice in order to overcome the issues that have arisen in that moment. Thus, practitioners’ intentions and goals change as new goals emerge that direct their actions (Leont’ev, 1981). Returning to Saxe’s exploration of the practice of children’s candy selling activities in Brazil, Saxe (1991) referred to emergent goals as part of a framework he developed as a result of his research. In Saxe’s sense, emergent goals are the – sometimes non-conscious – goals that emerge in activities that need to be achieved whilst participating in the practice – in his research’s case, related to children’s candy selling practice – usually when the children were experiencing problems during their practice. Such emergent goals might be goals that emerge during ‘breakdown’ moments.

Considering that this research aims to investigate mathematics-related actions within the context of an activity in which players are acting within the virtual world of a digital game in out-of-school settings, it is important to view the context as paramount and account for the fluidness of the actions that constitute this activity. Saxe’s (1991) socio-cultural model of emergent goals is briefly presented next because an adapted version of this model informs the theoretical background of my research (see Section 3.2.2, in p.53).

2.2.2 Saxe’s socio-cultural model of emergent goals

In his study of candy sellers’ activities, in Brazil, Saxe (1991) developed a framework, consisting of three components in order to investigate the strategies and techniques that children used in the practice of selling candies in the streets. Within this framework, one is able to analyse the interplay of culture and individuals’ goals (and cognitive process) as it occurs within a practice (Saxe, 1991, 1999; Saxe & Esmonde, 2004). This is achieved when close attention is paid to individuals’ goals as they emerge within the practice (Component 1: emergent goals) and the analysis of the form-function cognitive shifts that individuals do in order to achieve their goals (Component 2: form-function shifts). Then, the way individuals transfer their form-function shifts that were acquired in one practice into other practices, describes Component 3 (see Saxe, 1991, 1999 for more).

Saxe's (1991) emergent goals component is consisted out of four parameters. This model suggests that, for example, candy sellers' goals that emerge during their activities in their situated practice, are shaped and affected by their *social interaction* with each other or with other individuals involved in the practice (i.e. buyers), by their *prior understandings* that they bring in the practice (i.e. existing knowledge), by *conventions and artefacts* related to the activity and lastly, by the whole *activity structure.* In particular, the first parameter, *activity or goal structures*, are all the tasks that are involved in the practice, for example in the practice of selling a candy, the candy seller, besides selling the candies, he first needs to buy candies from retailers and so on. The second parameter, *social interaction* refers to the interaction amongst the participants in the practice and argues that, for example, when young sellers interact with more experienced sellers they get informed regarding strategies and techniques that might help them in their practice and this has an impact on the formers' goal formation, as they would make different choices as a result of such interactions. The third parameter involves *cultural conventions/artefacts* such as cultural forms, conventions and representations that emerged "over the course of social history" (Saxe, 1991, p.18) including sign forms, currency systems and other tools at hand to help the sellers accomplish their goals. The fourth parameter refers to the *prior understandings* that individuals bring to the practice, such as previous knowledge, strategies and understandings that "…both constraint and enable the goals they [individuals] construct in practices" (Saxe, 1991, p.18).

Saxe's four parameter model provides a socio-cultural framework that views the (cultural) context as paramount and captures the context's influence on the activity that is being observed. The activity, in this case, is tool-mediated activity as it involves a digital game. Therefore, at this point, I will briefly review literature related to Activity Theory, tool-mediated activity and resources which is relevant to the theoretical background of this thesis.

2.3 Tool-mediated activity and resources

Many variations of socio-cultural theory exist as shaped by Russian psychologists and Vygotsky's concept of mediation (Engeström, 2001; Zinchenko, 1995). In order to inform the theoretical framework chosen for this research, a brief overview of Activity Theory and its generations are outlined next.

2.3.1 Activity Theory generations

Activity Theory is a theory in which the unit of analysis is the *activity* of *Subjects* (individuals) mediated by *Mediational Tools*, such as machines, gestures, discourse etc. in order for subjects to reach their *Object* (outcome, intention, goal) (see Nardi, 1996 and Engeström, 1999). These three concepts are being placed within a triangle as shown in Figure 2-1 below (Engeström, 1999). Activity Theory was formed by Vygotsky's idea of bringing together individuals' actions and mediational means in his attempt to conceptualize mind consciousness (Edwards, 2011).

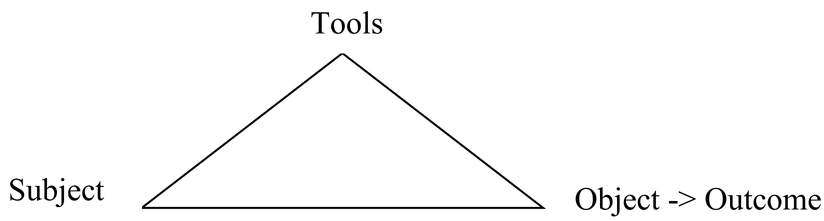

Figure 2-1: Engeström's (1999) Activity Theory triangle

Several adaptations of this theory have been made. For example, Engeström (1999), in a historical overview of three generations of Activity Theory, refers to the addition of three more concepts in the original triangle which forms Activity Systems; *rules* (formal and informal)*, community* (i.e stakeholders) and *division of labour* (work responsibility of each individual). Engeström (2001) proposed that the unit of analysis should be Activity Systems (second generation) and later on, contradictions occurring within the systems (third generation) when attempting to understand complex learning environments set in individuals' practices, such as their work. For more on Activity Theory, see Leont'ev (1974, 1978, 1981), Engeström (1999) for the three generations of Activity Theory and Nardi (1996) and Kuutti (1991) for Activity Theory application in Human Computer Interaction.

2.3.2 Leont'ev's Activity, Action and Operation hierarchy

Throughout the years, the application of the first generation of Activity Theory in research, revealed some issues (Gonzalez, 2006; Diaper, 2008). Questions such as "What comprises activity and how is this activity different from an action?" and "What is the unit of analysis within such an approach?" were put forward by socio-cultural analysts. Coming from the former Soviet Union's Kharkov school, one of the main contributors of Activity Theory, Leont'ev (1974), was the first to make an analytical hierarchical distinction of the levels of human behaviour. He referred to *operations* as being constituents of *actions* which in their turn are constituents of *activity*. In order to distinguish action and activity, Leont'ev (1981, p.61) stated that: "When a concrete process – external or internal – unfolds before us, from the point of view of its motive, it is a human activity, but in terms of subordination to a goal, it is an action or chain of actions". Building on Leont'ev's distinction, Davydov (1985, p. 40) added that: "when an activity loses its motive it can become an action, and when an action loses its goal it can become an operation". In other words, operations, actions and activity are not separated from each other. Rather, actions and operations carry out the activity, where actions are constituents of activity and operations are routinized actions, actions without a goal. What Leont'ev proposes here, is that a researcher might study the same event from different viewpoints; from a macro perspective focusing on object-oriented activity, from a meso perspective focusing on goal-directed actions and from a micro perspective focusing on routinized operations and goal-directed actions (Leont'ev, 1981; Wells, 1993).

2.3.3 Artefacts, tools and resources in out-of-school mathematics

A basic principle of Activity Theory, as it was set by Russian Psychologists, is the unity and inseparability of consciousness (i.e. human mind) and (external) activity. When individuals are participating in an external and practical activity and are interacting with the material world, their mind is also 'acting'. "…[A]ctivity that is internal in its form, originating from external practical activity is not separated from it and does not stand above it but continues to preserve an essential two-fold connection with it" (Leont'ev, 1981, p.97). Thus, when individuals get involved in an 'external' (physical) activity by interacting with their material world, their activity is being shaped by this material world. During this activity, the process of turning an external materialized interaction into a process in the mental plane of human mind is what Leont'ev characterized as *'interiorization'*, following Vygotsky's work. Additionally, individuals' activity often results in shaping their material world. Leont'ev characterized as *'exteriorization'* the process in which *'internal'* (mental) activity is turning into an *'external'* activity by materializing into artefacts. These internal and external processes are inseparable and in order to understand human activity, both the internal and external 'side' of the activity must be studied (Kuutti, 1995).

Looking at the basic triangle of Activity Theory, apart from the *subject* (participant) and the *object* of the activity, an important part is the *tools* that mediate the activity. Going back to the practice-linked mathematics research, it is clear that the practitioners used available tools and resources in order to proceed with their workplace activities. The tool(s) of an activity can be anything that is being used, shaped, changed and developed in order to transform the object of the activity into the outcome as it was set by the individual (Kuutti, 1995). From a psychological perspective, Vygotsky (1978) referred to the functions of *signs* and *tools* as indirect mediated activity. Object transformation is what Vygotsky (1978, p. 55) refers to as the main difference between signs and tools. He states that the mediating function of a tool is to "serve as the conductor of human influence on the object of activity" and is a "means by which external human activity is aimed at mastering, and triumphing over, nature" and thus is being "externally oriented". Vygotsky (1978, p.55) refers to signs as being "internally oriented" and serves as a "means of internal activity aimed at mastering oneself". However Monaghan (2016a) argues that both *'interiorization'* and *'exteriorization'* processes are important.

In respect to mathematics, Monaghan and Trouche (2016) in the introduction to the book *"Tools and Mathematics: Instruments for learning*" offer some valuable distinctions related to tools that help understanding what is a tool. Monaghan makes a distinction of tools and artefacts stating that: "An artefact is a material object, usually something that is made by humans for a specific purpose … [and] becomes a tool when it is used by an agent, usually a person, to do something" (p.6). He goes on saying that there is a difference between the artefact/tool and the ways that it is being used and that it requires some kind of *'mental representation'* in order to perform actions with a material artefact/tool. In addition, he makes a distinction between tools and signs as: “Signs, like tools, are artefacts but a sign signifies/points to something whereas a tool does something” (ibid., p.7). Trouche, defines a tool as specified by four dualities (ibid., p.7-8): acting “is both a process of using and creating artefacts” and “…the artefact shapes the way the user is acting [… and] the user shapes, along the course of her/his situated action, the artefact that s/he appropriates”. In addition, “the process of using an artefact is both a process of producing something and a process of constructing knowledge” and to Trouche, the “tool is a thing somewhere on the way from artefact to instrument” where instrument “[is] the mixed entity composed of the artefact and the associated knowledge (both the knowledge on the artefact, and the knowledge on the task constructed when using this artefact)”.

Let us take for example the pencil. A pencil is an artefact that was created by humans in order to mediate the activity of writing over the course of history. It is a tool for writing when the user-agent (subject in terms of Activity Theory) uses it in order to write something (object). But this is one way that the specific artefact (pencil) can be used as it has been used in other ways. For example, another way a pencil is being used as tool is in order to serve the object of the activity of solving the problem of a loose tape of a cassette tape (another artefact). I, as many others in the world, came across the same problematic situation of getting a loose tape. Using the – at hand – artefact of a pencil as a tool and specifically the hexagonal shape of most pencils’ wooden body in one (or both) that fits well in the cassette’s reel, I was able to solve that problem in an unorthodox, yet efficient way for returning the loose tape in its original state. Once the object of the activity was accomplished, the pencil returns to being an artefact. In this situated action, I, the user, shaped the way the artefact was used. I used knowledge regarding the shape and size of the pencil and the shape and size of the cassette tape reel and in similar situations that happened several times after that, the specific artefact *along* with the knowledge, associated with this unorthodox use of the artefact makes it (in respect to Trouche’s instrument sense) a “thing somewhere on the way from artefact to instrument”: a tool.

The above example is a simple example of the way an artefact becomes a tool in acting and it is an example of a problem that one might come across in out-of-school settings. Wartofsky's (1979, p.202) categorises artefacts in three levels; "primary artefacts" as the artefacts that are "directly used in this production", "secondary artefacts" which are representations and appropriations of the primary artefacts and "tertiary artefacts" as artefacts that can "constitute a relatively 'autonomous' world in which the rules, conventions and outcomes no longer appear directly practical, or which, indeed, seem to constitute an arena of non-practical, or 'free' play or game activity" (ibid, p. 208) and "in which there is free construction in the imagination of rules and operations" (ibid, p.209). In the context of simulation digital games' gameplay, Squire's (2004, p.81) research claimed that a history simulation digital game which was not designed for educational purposes (Civilization III), was "a primary artifact when used as a tool for gameplay and a tertiary artifact when used to remediate understandings of world history" as players engaged in a 'free' play whilst playing that particular digital game.

Returning to the research on mathematics in workplace (and out-of-school settings), the problems that they faced were "inextricably linked to the workplace context" (Maganja & Monaghan, 2003, p.120) and the artefacts and resources the practitioners (and candy sellers) used where different than the tools and resources that are used in schools. In particular, Schliemann and Carraher (2002, p.245) referring to the 'street mathematics' that was reported in Nunes et al. (1993), highlight that:

> "The mathematics children come to use and understand in everyday situations may draw upon the same underlying properties they will learn about in school. However, these properties arise in very different systems of representation and in different motivational contexts (e.g., mental computation based on the structure of the monetary system used in everyday activities versus the written computation algorithms taught in schools)".

Noss and Hoyles (1996a, p.34) referred to *'Mathematics-in-activity'* as being "characterised by its mobilisation-in-use: its meanings derive from the need to solve a problem, or to achieve a specific outcome […] it is part of the action […and] the activity is not constituted by its different elements (say, mathematical, physical, social) but by the dynamics of the activity as a whole". Noss, Hoyles and Pozzi (2002) concluded that within a practice, the "mathematical activity is anchored in the artefacts and discourses of the practice" (p.227) and Hoyles (2003, p.4) posits that mathematical relationships may be captured within the tools of an environment "but these relationships lie dormant until they are mobilised, and it is in their mobilisation that meanings are created".

This complexity of the nature of mathematics in out-of-school settings is undeniable and the difficulty in linking in-school and out-of-school mathematical practices is an ongoing issue in mathematics education (Monaghan, 2016b). Adding to this difficulty is the issue of being able to recognise mathematical activity in such complicated contexts in out-of-school settings as "it is recontextualized in ways that sometimes make it difficult to recognize at all" (Noss, Hoyles & Pozzi, 2002, p.227). In their extended research in mathematical meanings via the mediation of computer software, Noss and Hoyles (1996a) suggest that the computer can be perceived as a 'window' that can make students' mathematical meanings visible. As they state: meanings "can be derived from being recognized by a computer. This recognition involves a dialectical interaction between tool and language in the course of interaction" (Noss & Hoyles, 1996a, p.129). The above statement refers to the interaction of individuals with computer, tools and language, as a window to view individuals' mathematical meanings.

Mathematical meanings are perceived by (Noss & Hoyles, 1996a) as: "a relationship between person and knowledge" (p.129) which is "…maintained by involvement in the process of acting and abstracting, building new connections whilst consolidating old ones" (p.49). In other words, actions are central to the construction of mathematical meanings. Within such actions, the construction of new knowledge is linked to the negotiation and consolidation of previous knowledge that is brought in the acting. Mezirow (1994, p.222-223) proclaims that learning is "the social process of constructing and appropriating a new or devised interpretation of the meaning of one's experience as a guide to action". Learning is therefore, linked to individuals' meaning-making process through their experiences and social interactions and the consolidation of previous knowledge towards the construction of new or negotiated knowledge. This fits well with the socio-cultural theoretical framework of Activity Theory applied by many researchers in Human Computer Interaction studies (Diaper, 2008).

Nonetheless, in mathematical activities which involve the use of a computer, the kinds of resources which learners can draw upon as a scaffold vary. Noss and

Hoyles (1996a, p.108) referred to '*webbing'* as an idea which "is meant to convey the presence of a structure that learners can draw upon and reconstruct for support – in ways that they choose as appropriate for their struggle to construct meaning for some mathematics" in computational settings. This idea of webbing extends scaffolding in three ways (ibid, p.109): i. the subject takes "what is supportive from the ambient pedagogical setting, rather than 'receiving' what is given", ii. webbing is "domain contingent […] it focuses attention on the influence of the setting and the symbol system within which the ideas are expressed" and iii. "…there are connections built into the structure of the environment, and even signposts which assist in navigation: yet the structures discovered, and the signposts followed (and ignored) are largely in the hands of the learner". Relevant to Noss & Hoyles (1996a,) idea of webbing is Luckin's (2010a, p.162) "Ecology of Resources" model of context. This model expands the idea of Vygotsky's zone of proximal development and "considers the resources with which an individual interacts as potential forms of assistance that can help that individual to learn. These forms of assistance are categorized as being to do with Knowledge and Skills, Tools and People and the Environment". Both 'webbing' idea and 'Ecology of Resources' model set learners and context in a centre place where learners interact with the context, taking what is supportive from the context in order to construct meanings in complex settings and complex activities.

Focusing on the activity of playing digital games on computer, it is argued that "[g]ameplay always has a mathematical aspect as games have rules […] and these rules include sequencing actions" (Monaghan, 2016b p. 338-339). Can this mathematical aspect be recognised through the window of the computer screen when players play digital games? The interest of research considering the affordances of digital games in mathematics learning is growing as it is documented in the recent book *"Digital games and mathematics learning: potentials, promises and pitfalls"* (editors: Lowrie & Jorgensen (Zevenbergen), 2015) as part of the Mathematics Education in the Digital Era series. As Logan and Woodland (2015, p.301) conclude in the end of this book that digital games, both educational and commercial[3], have "enormous potential" as they can act as a means where learning environments of several settings (school or home) can be brought together and "complement each other rather than competing". At his point, it is essential to review literature relevant to the medium which is involved in the activity being observed in this thesis: digital games.

2.4 Digital games, gameplay and engagement

This section aims at: i. reviewing the ongoing debate regarding the effectiveness of digital games for learning, ii. discussing the several definitions and labels that digital games have in literature and clarifying the way digital games are perceived in this thesis, iii. reviewing literature related to gameplay and players' engagement during gameplay and lastly, iv. reviewing literature related to open-world simulation sandbox games, presenting (briefly) *The Sims 3* digital game and explaining the rationale for choosing it for this research.

2.4.1 Debate on digital games and their effectiveness for learning

The rapid growth of the gaming industry could not have been ignored by educational research. In fact, over the past decade, a great body of research investigated games' effectiveness in relation to learning in a debate that is still ongoing (Steinkuehler & Squire, 2014). In their quantitative meta-analysis of 32 studies, Vogel, Vogel, Bowers, Bowers, Muse & Wright (2006) found that when games and interactive simulations are used in classrooms, students' cognitive gains and attitude towards learning are higher in comparison to traditional means of teaching. In an extension of Vogel et al. (2006) meta-analysis and with a focus on additional instructional and contextual factors, Wouters, van Nimwegen, van Oostendorp & van der Spek (2013) conducted a meta-analysis of 38 – more recent – studies that compared serious games[4] with conventional instruction methods confirming that serious games are more effective in terms of cognitive gains and retention of knowledge in comparison

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[3] These definitions are clarified in Section 2.4.2, in p.23

[4] Serious games are games in which education is the primary goal rather than entertainment (See Section 2.4.2)

to traditional teaching. Nevertheless, they unexpectedly found that serious games were not more motivating than conventional instruction methods. This was also one of the findings of Sitzman (2011) quantitative meta-analysis of the effectiveness of computer-based instructional simulations, as compared to passive conventional treatment.

In addition, a recent qualitative meta-analysis of 89 research articles that provided empirical data, conducted by Ke (2009), claims that computer instructional games appears to have some positive effect on learning of the subject-matter that were developed to 'teach'. However, the studies used in Ke's (2009) meta-analysis include studies in which the treatment was not clearly described. In contrast to Ke's (2009) inclusive meta-analysis, Young, Slota, Cutter, Jalette, Mullin, Lai et al. (2012) identified 363 studies related to digital games' (including commercial digital games[5]) effectiveness for learning, but only 39 studies (approximately 11% of the 363) were eventually included in their qualitative meta-analysis revealing the lack of sufficient empirical evidence supporting the effect of games on academic achievement, especially in science and mathematics.

Examining the ongoing debate regarding the effectiveness of games in respect to learning, valuable insights can be drawn:

- Most meta-analyses studies only included games that were one way or another especially designed to be used for educational purposes and excluded studies that involved commercial title games (Vogel et al., 2006; Ke, 2009; Sitzman, 2011; Wouters et al., 2013). Only Young et al. (2012) meta-analysis included empirical research involving commercial games.
- All quantitative meta-analyses excluded any research that did not involve a control group in drawing conclusions regarding the effect of such games in comparison to traditional means of teaching (Vogel et al, 2006; Sitzman, 2011; Wouters et al, 2013).
- A great number of the documents reviewed – and excluded from the meta-analyses of those studies – were theoretical and personal propositions of the

[5] A commercial digital game is a game that is created for entertaining purposes (See Section 2.4.2)

authors regarding the potential effect of games for learning (Ke, 2009; Young et al., 2012; Wrouters et al., 2013).

- The quantitative analysis of the studies that were included in most meta-analyses revealed the ambiguity of the empirical evidence supporting the effectiveness of serious games (Wouters et al., 2013), of computer-based simulation games (Sitzman, 2011), of interactive simulations and computer games (Vogel et al., 2006) on cognitive gains and motivation.

Despite the increasing interest of research and discussion of games and their effectiveness for learning, attempts for summarizing (and sometimes generalizing from) literature and empirical evidence supporting the effectiveness of computer games are difficult, revealing the ambiguity and contradictions among findings. Moreover, the games that most of those researches examined were games and simulations that were designed mostly for educational purposes and were implemented one way or another within a classroom. Digital games and their effectiveness (or not) in relation to learning *are* being discussed in literature. However, as pointed out by Steinkuehler and Squire (2014), when talking about digital games, are we talking about the same medium and are we measuring the same thing as being effective? For all authors who conducted the meta-analyses reports that were reviewed earlier, 'games' were perceived in a different way; instructional games (Ke, 2009); interactive simulations (Vogel et al., 2006); computer simulations (Sitzmana, 2011); serious games (Wrouters et al., 2013). Only Young et al. (2012) included, apart from educational games, commercial digital games. However, are all these 'games' the same thing? At this point I shall briefly discuss the several definitions of 'digital games' found in literature and clarify the 'digital game' definition that I use in my research.

2.4.2 Educational games, serious games and commercial games

Twenty years ago, Reiber (1996) characterized games as endogenous and exogenous. Endogenous are games where the context and gameplay are inextricably linked, such as in most of the *commercial or entertaining games*, whereas exogenous are the games where the context is extrinsic to gameplay and is mostly there due to motivational reasons, such as in most *educational games*. Nonetheless, there are commercial games, such as Flappy Bird[6] and Candy Crush[7], which are popular games that can be characterized as exogenous because their context is not inextricably linked to gameplay and is mostly there due to motivational reasons. Educational games are games in which education is the primary goal rather than entertainment and have several labels within literature (Michael and Chen, 2006; Connolly et al., 2012). Epistemic games (Shaffer, 2006), serious games (Zyda, 2005) or edutainment[8] (Egenfeldt-Nielsen, 2005) are some of them. Zyda (2005) in fact states that a serious game borrows some of the commercial digital games' characteristics but, it also adds another parameter: pedagogy and a pedagogy subordinate story.

The work of a number of researchers suggests that serious games can be "tools for constructing a viable learning experience" (Egenfeldt-Nielsen, 2006, p. 201) and "can aid in the learning process" (Annetta et. al 2009a, p.74) in many subjects (see Chuang & Chen, 2009; Connolly et al., 2012 and Kebritchi & Hirumi, 2008). The impact and outcomes of serious games on learning and behaviour include: "(a) knowledge acquisition, (b) skill acquisition, (c) affective, motivational and psychological outcomes and (d) behavior change outcomes" (Connolly et al., 2012, p. 672). Yet the majority of the meta-analyses that were reviewed earlier in Section 2.4.1 argue that evidence supporting serious games' effectiveness are vague. So, how 'pedagogical' or 'educational' are serious games, really? Kebritchi and Hirumi (2008) conducted a literature review of articles written and/or been published in the period of 2000-2007, referring to the worldwide use of serious games. They found 50 articles and 55 serious games of which, only 22 out of 55 were based on solid established learning theories, 2 out of 55 were based on some basic learning instructional theories, whereas in 31 out of 55 no pedagogical

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6 http://www.flappybird.com/

7 http://candycrushsaga.com/en/

8 Edutainment is a blended word consisted of the words: education and entertainment. As the term implies, edutainment software is developed under the idea of entertaining people while educating them. (Egenfeldt-Nielsen, 2005). Such software usually employs drilling activities (Denis & Juvelot, 2005).

foundation was identified. These findings add to the criticism educational games are facing in respect to whether they are actually doing what they are designed to do; offer educational learning opportunities under the camouflage of a computer game.

In addition, almost 20 years ago, Leyland (1996) marked that games for educational purposes did not do well in the market in comparison to the commercial games. He argued that this was because in edutainment (and serious games): "[t]he 'educational' content tends to come at the expense of the gameplay and control is taken out of the hands of the player" (ibid, p.1). Perhaps another reason for this low preference might be the fact that serious games are enriched with rules and structure and they lack a motivating story plot, graphics and meaningful scenarios (see Buckingham & Scanlon, 2002, Egenfeldt-Nielsen, 2005; Zyda, 2005). These differences in respect to the context's richness and value and also in the game's interactivity (Denis & Jouvelot, 2005) are important reasons why commercial digital games are more appealing to players and are more embraced in comparison to serious games or edutainment (Leyland, 1996).

It is not my intention to argue for the (lack of) educational affordances or effectiveness of some edutainment software by comparing them to commercial digital games. Most serious games accomplish their original goal as educational games by providing a virtual environment which can accommodate learning (Guillen-Nieto & Aleson-Carbonell, 2012). In fact studies have shown that some of those serious games titles, such as Supercharged!, were effective in Science learning (Barnett, Squire, Higgenbotham and Grant, 2004). However, this happens against other factors that are important for learning such as motivation, engagement, exploration, investigation and authenticity (Johnson & Johnson, 1985; Buckingham & Scanlon, 2002).

In other words, they lack elements that keep a player engaged and interested while playing a commercial digital game, such as the game's actual complexity and story (Annetta et al., 2009b; Annetta et al., 2009a). Educational games' developers argue that their games are not as appealing to target population because of the limited development budget they have in comparison to commercial games, yet some exogenous commercial games with poor graphics and low budget, such as *Flappy Bird* app game, managed to become so popular that its developer, Dong Nguyen decided to discontinue its availability because it was an addictive product (Nguyen, 2014).

Therefore a question arises: Are educational (serious) games' developers trying to develop state of art learning games following a, perhaps, derailed direction? Young et al. (2012) reviewed the trends in research regarding the use of serious games in education and – influenced by Super Mario commercial game series' context – partly titled their meta-analysis paper: *"Our princess is in another castle [...]"* arguing that the current status of research disregards the importance of focusing on: "the complex interaction of player–game–context" (ibid., 84). Could the use of commercial digital games in the classrooms *be* that 'other castle'? Gee (2003) already implied that good commercial games are designed following good learning theories and they are already state of the art learning games.

Nonetheless, very few researchers conducted evidence-based research in order to investigate the way commercial digital games' use in a classroom setting has aided in students' learning. For example, Squire (2002) investigated and argued that "*Civilization*" (commercial title game) gameplay had a positive effect on students' history and language learning when it was being used in a classroom. In another classroom use of videogames, Tanes and Cemalcilar (2010) investigated the gameplay of SimCity by Turkish 7th grade students and found that the experimental group, who played SimCity for six weeks, were influenced by their activity within the game and altered the way they perceived their ideal city. The above researchers reached their conclusions after comparing experimental groups with control groups in classroom settings. Nonetheless, other factors might have caused the differences that affected their results. For example, research has shown that the familiarity and experience that participants have with digital games affect the way they appreciate and interact with them (Bourgonjon, Valcke, Soetaert & Schellens, 2010). Not only that, players' profiles can have vast differences and players can choose to play a game while adopting several player identities (Gee, 2003; Squire, 2006; Cowely, Darryl, Black & Hickey, 2008). Additionally, not all children accept the use of videogames in their classroom as suggested by Bourgonjon et al.'s (2010) research. In addition, the setting in which such commercial games are being played might have an impact on gameplay. For example, studies in mathematics showed that when a non-classroom activity was carried out within the physical setting of a classroom, participants treated such an activity as a classroom activity (see Monaghan, 2007).

It is important to highlight that such commercial games are simulation games and more recently, studies investigating the use of digital games in classrooms turned to games that are open-ended simulation games – 'sandbox[9]' games – that allow players to edit the onscreen environment (Nebel, Schneider & Rey, 2016). At this point, it is important to first clarify the way digital games are perceived in this study.

2.4.2.1 Digital games definition(s)

There is no one single and absolute definition of digital games within the research community. In fact, digital games can be found in literature as videogames, computer games, electronic games and so on. Nonetheless, when either term is used, it typically involves a device (computer, console etc.) on which software (the game) can run, with a screen and an input hardware (either the device itself, or a mouse, keyboard, joystick etc.) to allow players to interact with the device and software (Kirriemuir, 2002). However it is essential to be straightforward regarding the way 'digital game' is being perceived in this study.

The definitions found in literature vary and go back in the 1950s where the first attempts of creating interactive electronic games were made (Kent, 2001) and are provided by several disciplines. A short and contemporary definition of videogames is offered by Salen and Zimmerman (2003, p. 96):"A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome". Similarly, game designer Chris Crawford (1984; 2003) considers games as a representation of reality in which players can compete with each other or with the computer in conflicts where attacks are allowed, but the consequences of their conflicts are not harmful to them in real life. For example, if the player gets killed in the game, the player is not dead in real life. Crawford (1984; 2003) as well as Salen and Zimmerman (2003, p.96) refer to "artificial conflict" and the element of

[9] Literature that reviews research regarding the use of sandbox games in educational research is provided in Sections 2.4.4.1 and 2.4.4.2 that follow, because the digital game that is involved in this thesis, *The Sims 3*, is a 'sandbox' game.

competition in their definitions of videogames because in one way or another, the player ends up winning or losing. In order to do so, s/he needs to compete either with another player or with the computer. These conflicts are the results of challenges that game designers recognize as essential elements for games and try really hard to provide within their games (Crawford, 2003).

Although Salen and Zimmerman's (2003) definition is satisfactory, I will adopt Jasper Juul's (2003) more detailed definition for this research. Juul's (2003) definition can be seen as an extension of Salen and Zimmerman's definition that he built upon the common elements he identified after reviewing and analysing the definitions of game and play[10] as provided by philosophers (i.e. Caillios, 1961; Huizinga, 1950; and Suits, 2005), game designers (i.e. Chris Crawford, 1984; 2003), researchers involved in game studies (i.e. Salen and Zimmerman, 2003) and others. Juul (2003, p.35, emphasis added) defines game as:

> "A game is a <u>rule-based</u> formal system with a <u>variable and quantifiable outcome</u>, where <u>different outcomes</u> are assigned different values, <u>the player exerts effort</u> in order to influence the outcome, the player feels <u>emotionally attached</u> to the outcome, and the consequences of the activity are <u>optional and negotiable</u>."

Juul (2003) perceives games as a formal system, which is rule-based and has a quantifiable outcome, the same way Salen and Zimmerman (2003) define games. He refers to game's consequences as being optional and negotiable and connects the game's outcome with assigned values, player's emotions and player's efforts. Hence, Juul's definition explicitly upgrades the player's essence within the game and his/her interaction with it – the gameplay – which is important in this research.

2.4.3 Gameplay and players' engagement

The game's complexity is highly related to the game's gameplay. The term 'gameplay' has ambiguous definitions in literature. Egenfeldt-Nielsen, Smith and Tosca (2008, p. 102) define gameplay as "the game dynamics emerging from the interplay between rules and game geography" whilst the player interacts with it. Hence, gameplay is referred to players' experience while interacting with the

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[10] Juul's table of definitions is provided in Appendix A (**p.226**).

game's system, following the game's rules (Salen & Zimmerman, 2003; Crawford, 2003). This experience is associated with players' feelings and emotions and the way "it feels to play a game" (Egenfeldt-Nielsen et al., 2008, p.101). Lindley, Nacke and Sennersten (2008) associate the emergence of these emotions with motivation, task performance and achievement. Establishing optimal gameplay experience is vital for most game designers as it is one of the prime reasons of players' preference (see Adams & Rollings, 2003).

Juul (2002) refers to two ways that game designers can design their game's gameplay structure; *emergence* and *progression*. He states that in an emergence game structure, "a game is specified as a small number of rules that combine and yield large numbers of game variations, which the players then design strategies for dealing with" (p.324) whereas in a progression game structure, "the player has to perform a predefined set of actions in order to complete the game" (ibid, p.324). A game that has an emergence game structure is often labelled as an open-world game or an open-ended game (Squire, 2008). Good gameplay is usually composed of a series of challenges, the accomplishment of which engages the players into a state of flow (see Csikszentmihalyi, 1990).

The element of '*challenge',* was described in Suits (1978) quite early definition of games as one of the substances of games, stating that rules prevent players from using more efficient means while playing and that players agree to this 'arrangement'. Suits (2005, p.50) proposed four elements of game: "1/ the goal, 2/the means of achieving the goal, 3/ the rules and 4/ the lusory attitude". The *goal* or outcome, according to Suits, is the *specific state of affairs* that the player wants to achieve and the means are those that, paradoxically, are less efficient, yet the only ones allowed by the rules of the game. It is the player's *lusory attitude* that makes him/her agreeing to those rules and consciously selecting less efficient means over more efficient ones. When you play Basketball for example, you cannot hold the ball and run without bouncing the ball along your way. Well, physically, you *can* but you *do not* because the game has rules, prohibiting you from doing that. When you play *Pac Man* you cannot just shoot the 'enemies' and move on, because you do not have the tools to do so, but the rules of the game require that you find your way using just the navigation buttons (up, down, left, right). The player needs to enter a game with the *lusory attitude* that Suits proposes and s/he has to figure out pathways of acquiring the objective with less efficient means. That, for a player, is a challenge.

Additionally, in a research of serious games' use in a classroom, Ahlfeldt, Mehta and Sellnow (2005) supported that students' engagement in gameplay increased when they were set in challenging problem-based activities. This echoes findings from other studies regarding students' motivation and engagement. For example, Schernoff, Csikszentmihalyi, Schneider and Shernoff (2003) found that participants' engagement was increased when the perceived challenge of the task and their own skills were high and in balance, when the instruction was relevant and where the task and learning environment were under their control. In other words, players' engagement is achieved best when they own a task that is relevant to them, when they are set in problem-based challenging activities and when the level of the activity is challenging, yet achievable.

Reviewing the current facts regarding the top 20 selling computer games[11] of 2015 in the USA (ESA, 2016, p.11), it appears that game titles such as *The Sims* game series, World of Warcraft, Grand Theft Auto, SimsCity and Fallout take 15 places of the top 20 ranking table. Even though they are games of different genre and are being played by players of a different age, those top selling computer game titles are franchises that share in common the fact that they are considered as open-world games; games that allow players to explore and roam through the game's digital world as they like, without the game's designers imposing a progression and often linear game structure (Squire, 2008; Juul, 2002). Therefore, it appears that players in the USA prefer buying open-world computer games, games that allow them to explore. But do students share the same preferences? In a recent study Hamlen (2011, p. 537) investigated 118 elementary school children's game preferences and motivations for playing digital games and found that children were mostly motivated

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[11] Digital games are being designed for several platforms and devices; computers, game consoles, smartphones and so on. Therefore, there are several tables reporting digital games' sales and rankings. For this research I present these 20 top selling computer digital games because *The Sims* 3 game that is being used in this research is a computer game title.

to play digital games the subject of which was interesting to them (25.6% highest motivation percentage), such as “playing a game simulation that relates to their interests”, digital games that allowed them “to do “almost anything” and to make choices for themselves” (13.9%) such as open-world sandbox games and challenging games that “are difficult and require them to think” (p.538). .

2.4.4 Open-world simulation sandbox games in education

Almost ten years ago, Squire (2008, p.192) suggested that “open-ended, sandbox-type environments […] are excellent places to start” for “creating theories of game-based learning environments” (ibid). Sandbox games are open-ended games that allow players to edit and manipulate the game’s on-screen environment (Tornqvist, 2015). Indeed, over the past decade, educational research has turned to popular commercial open-world sandbox simulation games (Marklund, Backlund & Johannesson, 2013), in order to investigate their potential for education because the open-ended nature of those games allow players to make changes to the game’s content (for example: Nebel, Schneider & Rye, 2016; Hsiao, 2009; Al-Washimi, Bana, Benson et al., 2014; Greenstein, Panorkou & Seventko, 2016; Avraamidou, Monaghan & Walker, 2012). Examples of commercial and popular ‘sandbox’ game titles are *The Sims* series, Minecraft, Spore and LittleBigPlanet. For the purposes of this thesis, in Section 2.4.4.1 I only review literature related to Minecraft because over the years, this popular game has been mostly used in educational research (Nebel, Schneider & Rye, 2016) and it shares some common gameplay characteristics with *The Sims 3* game which I use in my research. In Section 2.4.4.2 I briefly describe *The Sims 3* game, review related research and explain my rationale for selecting it for my research.

2.4.4.1 Minecraft in educational research

Minecraft is an open-world sandbox game, initially created by Markus ‘Notch’ Persson and later on developed by Mojang game developer (Nebel, Schneider & Rye, 2016; Wernholm & Vigmo, 2015) in which players break or place 3D blocks in order to shape the onscreen environment which is randomly generated by the game (Duncan, 2011) that consists of blocks. Despite the poor picture and graphics of this game, it rapidly became popular through the vast community that players of this game developed (Wernholm & Vigmo, 2015). It can be played as single player or multiplayer online and it has five main gameplay modes: Creative, Survival, Adventure, Hardcore and Spectator (Minecraft GamePedia, 2017). The open-ended gameplay of Minecraft allows players to set their own goals as they proceed with their gameplay. Minecraft provides players with several tools and resources to support their gameplay, however, depending on which mode players select to play this game, they encounter different levels of constraints and have access to different resources. For example, in Creative mode they have access to all resources and blocks available by the game, whereas in Survival mode they have to gather such resources. In addition, in Adventure mode players interact with blocks in a more constrained way, whereas in Survival mode players need to make sure they will survive by maintaining their avatar’s hunger and health levels high (ibid).

Ever since the game’s developers allowed players to add to the game’s content by creating Minecraft modifications (Mods) which they can share and download from several Minecraft communities, the game gained popularity and became one of the best-selling games of all time (ESA, 2016; MacCallum-Steward, 2013). Minecraft’s popularity and Minecraft mods lured several educators, who have some experience in coding, to develop and share Minecraft mods that could be used for education (Al-Washimi et al., 2014) and Minecraft developers developed Minecraft Education, a Minecraft-based platform in which teachers can develop their own open-world virtual classrooms. Due to this open-ended nature of the game, Minecraft’s educational potentials were reported in literature regarding history and architecture (Sáez-López, Miller, Vázquez-Cano & Domínguez-Garrido, 2015), language learning (Hanghøj, Hautopp, Jessen, & Denning, 2014), digital storytelling (Garcia-Martinez, 2014), computer science and programming (Zorn, Wingrave, Charbonneau & LaViola, 2013), motivation and collaboration increase (Wendel et al., 2013; Zorn, Wingrave, Charbonneau & LaViola, 2013) spatial reasoning (Lewis, Winer, Kellert & Chao, 2015) and arithmetic operations and problem-solving by creating calculators, numbers and mathematical shapes in mods for the players to use during gameplay (Al-Washimi et al., 2014). In addition, players’ online community activity has been researched in order to capture the way players instruct other players to create material in Minecraft through the creation of walkthroughs videos (Niemeyer & Gerber, 2015) and to capture the creation and sharing of

Minecraft mods and their dialogues as they share experiences online (Wernholm & Vigmo, 2015).

The interest of educational researchers for open-world games, such as Minecraft, is sound. However, the researchers presented earlier in Section 2.4.4.1, used modified additions to Minecraft (Mods and/or Education version) for the experiments in their research. Their experiments were conducted in educational settings, integrating curriculum material and tasks that they designed and implemented in the game's environment. However, as reported by Sáez-López, Miller, Vázquez-Cano & Domínguez-Garrido (2015, p.125), despite the fact that both teachers and students recognise the potentials of Minecraft Education version in respect to creativity and motivation, "there are no significant improvements regarding the academic results when applying MinecraftEdu in the classroom".

As discussed earlier in this chapter (see Section 2.4.2**)** the process of developing educational games is not an easy task because it involves integrating educational, pedagogical and curriculum-based material and, in this case, with teachers and educators becoming game designers whilst designing educational game-based tasks. Reporting on their scenario-task design and implementation of mathematical tasks in a modified version of Minecraft, Greenstein et al. (2016, p.1543) "witnessed the negotiations and interactions that were provoked between the instructional goals of the teacher and the desire of students to be agents of their own activity". Indeed, one of the challenges of integrating open-world commercial digital games in a classroom is when such task-irrelevant gameplay instances occur, as a result of the student-player's self-directed gameplay goals (ibid; Bourgonjon et al., 2010; Sandford, Ulicsak, Facer & Rudd, 2006).

2.4.4.2 *The Sims* 3 digital game and rationale for selecting it for this research

"*The Sims*" series are popular open-world simulation games, representing real life family relationships (Nutt & Railton, 2003) that allow players to control the lives and relationships of game characters and create houses for them. Ever since the first launch of *The Sims* game in the market in 2000, the game series sold more than 125 million copies (Sinclair, 2010). In fact, in 2008, *The Sims* franchise was declared by their creators, Electronic Arts, as the biggest selling computer game series ever (Howson, 2008). Currently, according to the ESA's (2016) facts regarding the top selling computer game titles, *The Sims* series (*The Sims 3* and *The Sims 4* and their expansion modes) appear in 8 of those 20 places in the top 20 ranking table, with *The Sims* 4 being the top selling computer game and *The Sims 3* ranking in the 3rd place in the USA. In fact, *The Sims* series has always been ranked in the top 5 selling computer digital games in USA as it is evident in all annual ESA reports from 2010 and onwards (ESA, 2010 – 2016). This suggests that *The Sims* franchise is a popular franchise that managed to retain its popularity over the years in the USA. But why is this phenomenon observed?

The Sims series games are not games in the conventional sense, because they do not explicitly involve conflicts. This is why *The Sims* series creator Will Wright, refers to the series as being digital toys rather than games (Wright, 2003). In fact, Will Wright initially conceptualised *The Sims* series as an architecture simulation game, perhaps because of the creator's architectural background (Pratchett 2002). A few years after the first game title of *The Sims* series was released, Juul (2003, p.43) placed *The Sims* series in the border line of being a game or not, because as he claimed: "Open-ended simulation games such as *The Sims* change the classic game model by removing the goals, or more specifically, by not describing some possible outcomes as better than others". Juul perceived this lack of goals as an element that might disclose *The Sims* from being a game, however, perhaps this exact removal of goals is the reason why this series is doing so well in the market (ESA, 2010 – 2016; Leyland, 1996). Clark, Nelson, Sengupta and D' Angelo (2009) argue that even though *The Sims* games are simulations, players' goals and the challenges they set for themselves in the game, make it a game. Indeed, Gee & Hayes (2010) refer to a number of ways *The Sims* players played the game under several scenarios that they had developed, such as playing the game with a household that has a small amount of Simoleons[12]. Today, the popularity of open-world games such as *The Sims* series and Minecraft resulted in the genre of open-world games. Specifically, *The Sims* series is often categorised as a real-life open-world simulation game (Nutt & Railton, 2003; Montes & Cambell, 2013).

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[12] Simoleons is *The Sims*' game currency

As sandbox games, *The Sims* series games do not involve competition with other players or with oneself, as there are no explicit goals that a player can pursue apart from controlling the life of the game's characters. The player can engage with the game on an open-ended basis by experimenting whilst editing the onscreen environment, creating Sims characters, houses and neighbourhoods from scratch and this kind of activity is an integral part of "*The Sims*" game series. Players can create their own game characters from scratch or choose to play with existing game characters in the Live mode of the game. The player's overarching aim, as described by the game, is to ensure their Sims characters are alive and happy by performing actions, using the game's features and menus, such as fulfilling their characters' desires and attending to their Sims survival – and other – needs (i.e. feeding them). Their Sims needs and motives are displayed when players are playing with the Live mode of the game and there are respective meter bars that change according to the players' actions during gameplay, following the game's rules and mechanics.

When players are building or editing their Sims' houses, they play with the Build and Buy mode of the game (pausing the Live mode, if a Sims family is involved in gameplay) and using the respective Build and Buy mode menus[13], players can buy items for their Sims and their houses, such as furniture, decorations and so on. Buying or selling items in *The Sims* series game are processes that involve the game's currency which is called Simoleons. Each Sims family has an amount of Simoleons (budget) to spend which increases or decreases depending on the players' actions during their gameplay. In fact, Montes and Cambell (2013) criticised *The Sims* series, arguing that the game's mechanics that govern the happiness levels of *The Sims* virtual characters, promote virtual consumerism because Sims characters become happier when players buy many, luxurious and expensive items for their Sims. The gameplay of *The Sims 3* game in particular will be further illustrated in Chapters 4 and 6, where screenshots and descriptions of players' gameplay will be provided.

[13] Players can buy *The Sims* expansion packs (sold separately) in order to expand the basic game's options and menu items.

Similarly to Minecraft, *The Sims* players' creativity was researched, as they were reported modifying and generating content in the game that they later share in the game's communities (Sihronen, 2011; Wirman, 2011). *The Sims* 'Modders' or 'Modifiers' (Sihronen, 2011) or 'Skinners' (Wirman, 2014, p.58) are "tech-savvy players, who find excitement in not accepting software as a fixed composition". Although *The Sims* series' designers did not develop tools, enabling players to change and build on the game's code, like Minecraft creators did, players are able to share and download Sims artefacts/creations through the game's communities. In contrast to Minecraft, *The Sims* series do not have mods, packs or educational versions to enable teachers creating educational material within the game.

Nonetheless, due to the real-life simulation aspect of the game, over the years, *The Sims* series has been used in several educational research implementations (Iversen, 2014). A couple of years after the first game of the series was released, Nutt and Railton (2003, p.577) highlighted the way the game represents real-life conceptualisations and the way "players are active agents negotiating both the game's version of real life and their own real-life experiences". Taking into consideration this real-life simulation features of *The Sims*, Miller and Hegelheimer, 2006 (p.311) referred to game as "popular authentic simulation" game and conducted research in order to investigate the potential of *The Sims* as an environment that could be used in combination with supplementary English language material to improve adult ESL (English as a Second Language) students' vocabulary and language. The researchers reported improvement of students' English vocabulary and language use, when the game was used in combination with the supplementary material. Similar findings were reported by Ranalli (2008) who investigated the integration of *The Sims* game with the support of supplementary English language material, in classrooms with adult students. More recently, Andreassen and Syvertsen (2016) used *The Sims* 4 game's expansion packs – Sims 4: Get to work expansion – in order to train adults regarding work related skills. This expansion pack allows players to run a business, such as a store, in the game and engage in related store-running activities, such as interacting with customers. Their research concluded that participants and course trainers showed a positive attitude towards the game as used in their research experiment. Similarly, Sandford, Ulicsak, Facer and Rudd's (2006) reported that after interacting with scenario-based activities using *The Sims* 2 game in their classroom, students' motivation was increased. However, research investigating *The Sims* series' classroom integrations, as the ones described above, involved teachers' task-designed material and reached their conclusions after analysing participants' interviews, conversational observations and/or questionnaires' responses after participants interacted with the game. They did not analyse what participants-players actually did during their gameplay and interaction with the game.

Even though, *The Sims* series simulates real-life activities such as buy-sell transactions, following rules and constraints and involves processes of building ad decorating virtual houses from scratch, which, according to Gee and Hayes (2010), requires the player to use: "a good deal of geometry to get all the angles and shapes to fit perfectly together" (p.114), there is surprisingly no research, apart from my MA dissertation (see Avraamidou, 2007) to investigate *The Sims* series potentials in respect to mathematics. In my MA dissertation, I recorded and observed the gameplay of an 11 year-old boy, Costas, as he was building virtual houses in the *The Sims* 2 game. The results of my MA dissertation argue that Costas' mathematical prior understandings emerged whilst he was processing the goals that he had set for himself during his gameplay and was 'blended' with his everyday prior understandings and the game's artefacts (ibid; Avraamidou, 2012). It was also argued that an artefact and an accompanying strategy that Costas had developed and used in the game, during his gameplay, was a mathematical abstraction in context (see Avraamidou, 2007; Avraamidou, Monaghan & Walker, 2012).

In this section, I showed that *The Sims* series games are popular, ergo engaging, games, that allow players to 'freely' proceed with their gameplay, setting their own goals in an open-ended basis, but at the same time they constrain players' gameplay because, as games, they come with rules and specific digital content. The series simulates real life activities and family relationships and allows players to experiment without real-life consequences (Nutt & Railton, 2003) and it is a game, the narrative gameplay of which, can "initiate and powerfully facilitate players' identity construction, evoking reflection about their gameplay, multi-identities, the world and themselves" (Hsiao, 2009, p.226). In addition, prior research has reported mathematics-related activity emerging when creating virtual houses in *The Sims* 2 game, without teachers' involvement (Avraamidou, 2007; Avraamidou, Monaghan & Walker, 2012). For these reasons the latest version (at the time of designing this research) of *The Sims* series: *The Sims 3* was chosen.

2.5 Revisiting mathematical thinking – Operational definition

Returning to Section 2.1 mathematical thinking is associated with problem-solving, reasoning and plan formation in order to deal with mathematics-related activities. However, mathematical thinking is not only being developed within a classroom and via textbook-like problems and activities and has been researched in out-of-school settings, such as workplace settings and in the streets as Section 2.2 illustrated. Devlin (2011, p.59) views mathematical thinking as "a whole way of looking at things, of stripping them down to their numerical, structural, or logical essentials, and of analyzing the underlying patterns". Furthermore, Stylianides (2009, p.258), refers to mathematical thinking as a process that includes: "exploring mathematical relationships to identify and arrange significant facts into meaningful patterns" that can be later used in order to make conjectures and, as stated earlier, mathematical relationships, captured within the tools of an environment "…lie dormant until they are mobilised…" (Hoyles, 2003, p.4).

From the review of the literature that was presented in Sections 2.2 and 2.3, mathematics and mathematical activity that arises in out-of-school settings is not 'school-alike' mathematics, is driven by *"a need to solve a problem"*, is *"inextricably linked to the context*", is *"characterised by its mobilisation-in-use", "constituted by the dynamics of the activity as a whole"*, *"involving the use of tools and resources", "anchored in the artefacts and discourses of the practice"* and is different than, yet influencing and is influenced by, the formal mathematics being taught in schools.

Considering in particular, the context of digital games and gameplay activities, the player's intentions (goals) flow in order to reach optimal experience (Csikszentmihalyi, 1990), similarly to the way intentions flow within a practice either in job-settings (i.e. Noss, Hoyles & Pozzi, 2002; Magajna & Monaghan, 2003), in the streets (i.e. Nunes, Schliemann & Carraher, 1993; Saxe, 1991) or in everyday life's activity such as supermarket shopping (see Lave, 1988; Roggof & Lave, 1984). Actions during gameplay are directed by goals that might emerge and be shaped similarly to what Saxe's (1991) emergent goals model illustrates. In respect to digital games as a medium for learning, after reviewing several commercial game titles, Devlin (2011, p.127) claims that: "many successful games already on the market actually do require that players carry out certain kinds of mathematical thinking, among them logical problem solving, comparison of numerical ratios, scale conversions, etc.". He also suggests that a digital game that aims in developing mathematical thinking should focus on: "the development of real-world-applicable mathematical thinking involving everyday mathematics that the learner can make immediate use of in the world" (Devlin, 2011, p. 165). Thus, mathematical thinking in the context of a real-life sandbox simulation commercial digital game such as *The Sims 3* lies within the mathematical relationships that are dormant in the digital game until they become mobilized during gameplay, through the interaction of the players with the content, rules and geography of the digital game (Egenfeldt-Nielsen, Smith and Tosca, 2008).

Thus, in this research, mathematical thinking is perceived as a: *cognitive/physical activity (in the sense of Activity Theory's activity) in which mathematical (i.e. arithmetic, algebraic, geometric, logical, etc.) relationships are explored, is prompted by a need (intrinsic/extrinsic) and is evidenced through mathematical actions (cognitive/physical)*.

Drawing on the results of my MA research (Avraamidou, 2007), it was expected that in *The Sims* series' gameplay such mathematical actions could be (but not limited to) numerical or arithmetic, geometric, logical and algebraic. More specifically, as evidenced by the results of my MA study (see Avraamidou, Monaghan & Walker, 2012, p.9), the kind of mathematical actions and mathematical prior understandings that Costas (the 11 year-old boy who participated in my MA study) employed during his gameplay involved: i. Calculating (adding, substracting, multiplying, dividing) and comparing the cost of the game's virtual artefacts such as furniture and other menu items, ii. Comparing and manipulating the size and position of the 3D game's virtual artefacts so as to shape a virtual house in a symmetrical desirable way and iii. Performing actions related to problem solving processes, such as working within the restrictions of a given budget, thinking of ways to save on the family's budget and/or increasing the available budget.

In particular, during Costas' gameplay, in order to be able to find the middle of an odd number of cubes (the minimum area that *The Sims*' virtual artefacts can take) which was important to him, because he wanted to make his house symmetrical and because he wanted to create a cost-efficient house, Costas constructed an artefact-strategy of two cubes that he used as point of reference in order to make calculations and identify the middle of odd number of cubes. Realising what he knew from the trial and error actions in his gameplay, Costas "established the relationship between this artefact-strategy and calculations and then he foregrounded and used this artefact-strategy to do mathematics to build a cost-efficient house" (ibid, p.18). This example, which is discussed in Avraamidou, Monaghan & Walker (2012), is an example of the way mathematical relationships can be explored and mathematical actions are performed when prompt by a need, in *The Sims* series' gameplay.

2.6 Summary and research questions

This chapter reviewed literature related to mathematical thinking, mathematics in workplace and out-of-school settings, tool-mediated activity and resources and digital games, gameplay and players' engagement. Literature regarding mathematical thinking and mathematics in workplace settings reports that mathematics does emerge in everyday life activities, in workplace settings and – overall – in out-of-school settings. Yet, mathematics' related activities and mathematical thinking in such settings do not necessarily take the shape of classroom-based activities and textbook-like problem-solving, but are inextricably linked to the context in which they emerge and are being utilised by individuals within the specific context. In such out-of-school contexts, individuals (workers, practitioners, children and so on) use artefacts and tools at hand and research has argued that mathematical relationships might be buried within those artefacts and become mobilised as they are being used by individuals in order to achieve their goals which are formed as they proceed with their activities.

Playing digital games is an everyday, out-of-school, activity that both children and adults enjoy doing and research in the USA and the European Union has shown that the number of players has increased over the years. Digital games popularity lured educational researchers and practitioners to examine the use of digital games in education. However, reviewing literature regarding digital games and their use in educational research there appears to be an issue. One the one hand, educational games (serious / edutainment / epistemic games) are designed to carry out specific curricula content and aims, borrowing at the same time characteristics of commercial games but this pedagogical – educational focus, comes with the expense of lacking elements that are important to students/players such as motivation, exploration and investigation. On the other hand, because commercial games are not designed to carry out specific curricula content, teachers are reluctant in using them in a classroom setting for that reason and when teachers use them in a classroom they are usually being used as complementary.

But gameplay experience in commercial games, as it was designed and developed by the games' developers, was not intended to be complementary. It was designed to engage players into an immersive gameplay world so as to stand out and do well in the market of the digital games' industry. Gee (2003) argued that there are several good commercial digital games and Devlin (2011) argued that existing good games require players to carry out mathematical thinking. The majority of the frequent players themselves "believe that playing videogames provides mental stimulation or education" (ESA, 2016, p.6). As Squire (2008, p.107) argued almost ten years ago: "we need rigorous research into what players do with games (particularly those that don't claim explicit status as educational) and a better understanding of the thinking that is involved in playing them". Four years later, one of Young et al. (2012, p.84) meta-analysis' research conclusions and recommendations regarding research investigating the use of educational and commercial digital games for learning highlighted that: "research should focus on the complex interaction of player – game – context […] No research of this type was identified in our review suggesting the missing element may be a more sophisticated approach to understanding learning and game play in the rich contexts of home and school learning". It is, of course, acknowledged that Young et al. (2012) might have omitted such research in their meta-analysis, however, their suggestion that: "current methodologies must extend beyond their current parameters to account for the individualized nature of game play" (ibid., p.62) and not focusing on massive quantitative comparisons between experiential and control groups within a classroom, deserves a thorough investigation.

Current research regarding the use of open-world sandbox digital games showed that they have potentials for education because of such games' open-ended nature, confirming Squire's (2008) suggestion that such games can be a good starting point for creating game-based learning theories. Yet, gameplay in open-world sandbox digital games such as Minecraft and *The Sims* series can be quite complex and unpredictable because players can set their own goals and pursue them in several ways (Tornqvist, 2015). When such (modified by the teacher) games are integrated in classrooms, teachers' instructional goals are not always aligned with players' goals resulting in problematic integrations (Greenstein et al., 2016).

Before integrating such commercial games in school settings and producing supplementary curriculum-based material for classroom integration of such games, perhaps, we might need to take a step back and ask: Do we know enough regarding the way players' gameplay unfolds in such games in out-of-school settings before integrating them in classrooms? Do we know enough regarding the way players interact with each other either offline or online in the context of such games in out-of-school settings? Do we know enough regarding the kind of thinking and learning that might emerge whilst players encounter challenges and constraints during gameplay of such games, without a teachers' involvement?

There is, to the my knowledge, no research investigating mathematics and mathematical thinking that arises in the context of an open-world, sandbox commercial digital game, such as *The Sims* series, in out-of-school settings, without teachers' involvement, apart from my MA dissertation (see Avraamidou, 2007).

2.6.1 Research Questions

At this point, I remind the reader that the aim of this study is to explore mathematics that arises in the collaborative gameplay of *The Sims 3* digital game. In particular, this study seeks to explore the out-of-school collaborative gameplay of *The Sims 3* open-world sandbox digital game in relation to players' mathematical thinking. As stated in the Introduction chapter (p.5) the general research question that drives this study is:

How does players' mathematical thinking emerge and/or is affected while being engaged in the collaborative Activity of building virtual houses in The Sims 3 digital game, in out-of-school settings?

In order to answer the above general question, I will need to address the following research sub-questions:

1. What potential is there for mathematical thinking in *The Sims 3* as a game?

2. How does players' mathematical thinking emerge and how is it influenced when players engage in a less constrained and in a constrained gameplay?

3. How do players collaborate during a less constrained and during a constrained gameplay?

4. How do players' goal-directed actions emerge during *The Sims 3* gameplay?

Chapter 3 that follows presents and justifies the research design I employed in order to address the research questions.

Chapter 3 – Research design

Several research methods handbooks suggest different strategies for writing the research design chapter (see for example: Crotty, 1998; Denzin & Lincoln, 2000; May, 2002; Patton, 2002; Flick, von Kardoff & Steinke, 2004; Cohen, Manion & Morrison, 2011 and others). Crotty (1998) suggests that a research design should include four elements that inform each other, in order for the research's outcomes to be sound and convincing. These are *methods, methodology, theoretical perspective and epistemology*. Researchers should be able to describe the *methods* (i.e. observation, interviews etc.) they employ in order to gather research data and justify their selection by clarifying the connection of the specific methods to the desired outcomes using an appropriate *methodology* (i.e. ethnography, grounded theory etc.). Nevertheless, researchers need to go further than that and also describe the *theoretical perspective* (i.e. positivism, interpretivism etc.) that informs the selected methodology. Since most research seek to inform knowledge regarding an area, researchers need to be able to describe the way they understand the world around them and the way humans acquire knowledge. Thus, apart from the philosophical stance of their research, researchers need to identify, describe and explain the *epistemological* stance (i.e. objectivism, subjectivism etc.) they adopt as well.

The research design that was employed for the purposes of this study is presented in this chapter, considering Crotty's (1998) four elements. First, the epistemological stance adopted for this study will be discussed in Section 3.1, followed by the theoretical perspective that governs the selected methodology of this research in Section 3.2 and then, a description, justification and explanation of the methodology (Section 3.3) and methods (Section 3.4) employed in this study in order to gather and analyse (Section 3.5) the research data. Lastly, reliability and validity is discussed in Section 3.6, followed by a discussion of the ethical issues in Section 3.7

3.1 Epistemological stance

The qualitative and quantitative debate has been going on for a long time now (Denzin & Lincoln, 2000). Given the research questions of this study, a qualitative approach was followed. That is because the current study aimed in investigating participants' actions and their meanings when playing a video game collaboratively. Therefore, the researcher studied phenomena through participants' perspectives (Merriam, 2002; Cohen et al., 2011). So far, the epistemological field within qualitative research methods, has been various and hazardous (Patton, 2002; Given, 2008; Schwandt, 2000). Many authors have categorized epistemologies using several labels (usually ending in '–ism') such as 'subjectivism', 'objectivism', 'constructivism', 'constructionism', 'realism' and so on (Crotty, 1998; Candy, 1989; Higgs, 2001). The epistemology that informed this study, which lies more in the constructionists' camp, will be illustrated and justified.

Objectivism fits more with quantitative research and is mostly used in the natural sciences (Candy, 1989). Objectivists believe that "meaning, and therefore meaningful reality, exists as such, apart from the operation of any consciousness" (Crotty 1998, p. 8). Specifically, they believe that truth is scientific (Candy, 1989) and universal, waiting to be discovered (Crotty, 1998). Such a belief implies that meanings can be isolated and detached from context and we, as human beings, have no control of our knowledge, despite our life experiences. Subjectivists believe that knowledge is imposed by the subject to the object (Crotty, 1998). Such a position assumes that someone else (presumably a scholar in the area) fills in the mind with knowledge. However, applying subjectivism within social sciences is often difficult because as Hughes (1971, p. 508) states "the subject matter of sociology is interaction". Thus, when emphasising on the subjective imposition of meanings within actions, other aspects that might shape the meaning-making process of individuals, such as the social interaction of members of a community or relationships between group members' experiences and perceptions, are neglected.

Constructionists, on the other hand, believe that there is not one objective reality existing outside an individual, detached from his/her experiences (Given, 2008). Rather, humans' understanding, knowledge and meanings are constructed through interaction, either in formal instances, such as school and work or informal ones, such as everyday life interactions. In characterising epistemologies, Crotty (1998) uses the word *constructionism* in rather than *constructivism* in order to highlight the importance of *social* interaction. Crotty (1998) explains that a constructivist epistemology focuses more on "the "meaning-making activity of the individual mind" (p.58), whereas a constructionism epistemology focuses on "collective generation (and transmission) of meaning" (p.58) as a result of social interaction between humans (and their world). Crotty (p.3) describes it as "a way of understanding and explaining how we know what we know" This goes back to Piaget's (1978) constructivism and Papert's (1993; 1999) constructionism. Nonetheless, the way Crotty (1998) uses the term 'constructionism' is slightly different that the way Papert (1993) does. Ackermann (2001) elaborated on the difference of Piaget's and Papert's terminology as being on the *stability* and *change* of individuals' concept, respectively. Piaget focused on individuals' construction of internal stability as their learning evolves over time, whereas Papert focuses more on the way individuals' change their concepts meanings as they make things. Papert supported that individuals learn by doing, by interacting with tools and they can construct and re-construct their meanings by 'speaking' to their artefacts (Ackermann, 2001; Papert, 1993).

In this research, participants played a digital game which is a cultural artefact with cultural meanings (Greenfield, 1994; Bogost, 2007). Within a 'good' digital game (Gee, 2007), tensions between players' construction of meanings and thinking (players' selections, game strategies etc.) and the game designers' *'procedural rhetoric*[14]*'* are often observed (Bogost, 2007, p. ix). In particular, in this study, players built virtual houses collaboratively in groups of two and it was assumed that their activity was enhanced and affected by – among other parameters – their previous experiences and understandings regarding the world they live in and the negotiations while interacting with each other and with the game's world and rules (procedural rhetoric). *The Sims 3* players' mathematical thinking is not waiting to be discovered or imposed by others. Rather the players themselves, through their interaction with the game and with each other constructed meanings and developed their thinking. Thus, the epistemological stances of objectivism and subjectivism were not suitable to be followed here. This research aimed to record, understand,

14 'Procedural rhetoric' is a term introduced by Bogost (2007, p. ix) and is "the art of persuasion through rule-based representations and interactions rather than the spoken word, writing, images, or moving picture".

analyse and interpret participants' actions, thoughts, negotiations, strategies, decisions and constructions of meanings during an ongoing activity of gameplay of a digital game. For these reasons, this study fits more with the epistemological stance of constructionism.

3.2 Theoretical perspective

Following the constructionist epistemology, in this research, mathematics and mathematical thinking were expected to occur within a collaborative activity, mediated by a digital game and in an out-of-school setting. This mediation is a game that was designed to be an open-world simulation, a representation of real life (Electronic Arts, 2010). Thus, it was created and shaped by its designers according to the cultural norms, representations and conventions of real life (Bogost, 2007). Furthermore, it was assumed that players' thinking would be constructed and developed within the context of playing this game, which was of prime importance. For example, in a previous research of gameplay of the predecessor of this game, *The Sims 2*, the player referred to the rather unconventional identification of the 'middle' of 14 as the *'line between the 7th and 8th cube'* (Avraamidou et al., 2012, p.16) and not number 7 as he might normally answer if he was asked in a school-alike question, because this is what was meaningful for the player, within the context of the game, at that time. Thus, a socio-cultural theoretical perspective, which regarded activity as mediated and placed context as principal and integral to the analysis (Patton, 2002), appeared to be more suitable to be employed in order to inform this study.

3.2.1 Study unit of analysis

This research explored participants' mathematical thinking during gameplay. Thinking is often associated with an individual's meaning-making process (Krauss, 2005). Most social analysts set meanings and thinking as human constructions, such as culture, norms, perspectives, stereotypes, ideologies and understandings (Lofland & Lofland, 1996; Krauss, 2005). These meaning-making constructions are set by individuals through their interaction with external or internal contexts (Chen, 2001), through their experiences and interactions with other individuals within life and "are the cognitive categories that make one's view of reality and with which actions are defined" (Krauss, 2005, p. 762). Within this research, participants were engaged in an activity where the object/outcome was to build houses under objective conditions with which the activity was carried out (Zinchenko & Gordon, 1981). Participants were asked to play the game in groups of two because, almost always, when individuals collaborate it is in order to accomplish a shared goal (Hämäläinen & Vähäsantanen, 2011). Therefore, their talk was expected to act as a means to explicitly capture their thinking while they were negotiating and agreeing their shared goals throughout their gameplay.

Considering the above, the unit of analysis in this research is not the overall object-oriented activity of participants; to collaboratively build houses in this game. Rather, analysis will focus more on participants' actions which are constituents of activity (Leont'ev, 1981). Furthermore, players' actions during gameplay were expected to be goal-directed and it was expected that their actions would emerge along the way, as was previously observed in my MA dissertation (see Avraamidou, 2007). It was also acknowledged that as players would proceed with their gameplay, some of their – previously – goal-directed actions would become routinized actions: operations. Nonetheless, most socio-cultural analysts focus on individuals' actions and the intentions behind those actions in order to understand participants' activities (Krauss, 2005). In this research, it was anticipated that participants' thinking would be revealed to the researcher through those goal-directed actions and would be explicitly shared through their talk during gameplay. Thus, the unit of analysis for this research was players' goal-directed actions.

3.2.2 Adapting a socio-cultural model of emerging goals

In this research, players' goals will emerge during their ongoing, fluid and unpredictable activity of playing an open-world, sandbox digital game. Returning to Saxe's three component research that was earlier illustrated in Section 2.2.2 (in p.17) the first component of emergent goals was appropriate in order to inform the parameters that would emerge or affect those goals *within* this setting and was adapted to inform the theoretical framework for this research. However, this model was not adopted as it was. It was adapted in relation to everyday and mathematical understandings, players' interaction and talk, as well as the game's virtual artefacts, the players' artefacts created in the game and the cultural conventions and artefacts. Thus, those four parameters will be expanded as shown in the (preliminary[15]) diagram (Figure 3-1) below and will be discussed further next.

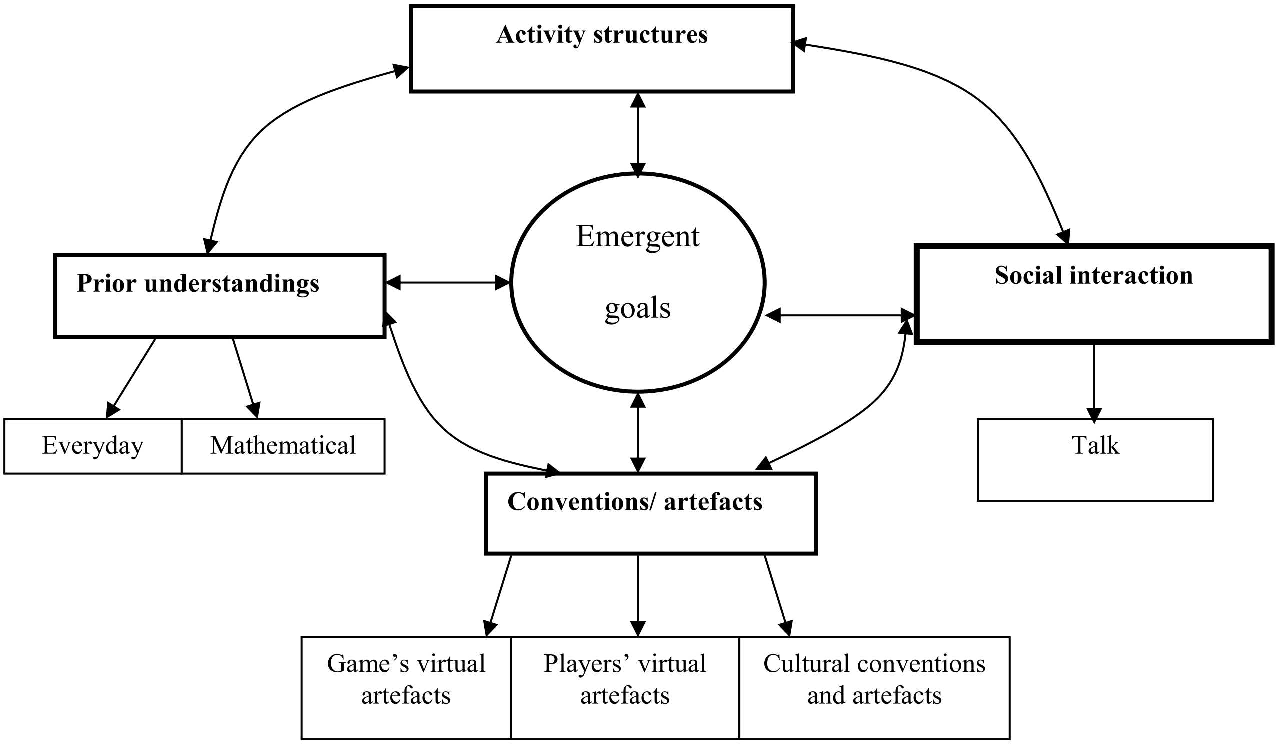

Figure 3-1: Saxe's (1991) adapted model

3.2.2.1 Social interaction

Participants were required to work together in order to complete the activities for the purposes of this research. In research, terms such as cooperation and collaboration are used to describe the way the members of a group work together in order to deal with, usually, a problem-solving situation (Hämäläinen, 2008). Members of both cooperative and collaborative groups share common goals and manage to accomplish their task eventually (Roschelle & Teasley, 1995). However, the

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15 It was acknowledged that after data collection, other parameters could have been added to the model, according to participants' actions. This shall be explained later in Section 3.5.2 (p.71).

difference lies on the process being followed to accomplish their task (Hämäläinen, 2008). For example, a group might work in cooperation in order to accomplish a task, by dividing the task into subtasks where each member of the group takes the responsibility to accomplish a separate part of the task (Dillenbourg, Baker, Blaye & O'Malley, 1996; Roschelle et al., 1995). Another group might work in collaboration by sharing and exchanging thoughts and ideas in their effort to jointly construct knowledge in order to mutually accomplish their task as a group (Mercer, 2010; McInnerney & Robert, 2004; Hämäläinen et al., 2011). In this research, participants were required to build shared virtual houses whilst working together using one computer. Thus, it was not expected that participants would split their task into subtasks. Rather, it was anticipated that participants would collaborate in order to accomplish their tasks (activities). They needed to explicitly discuss and negotiate their later moves together in order to proceed with their actions after exchanging ideas and understandings in order to reach a mutual settlement. For these reasons, player's interaction and their expected discussion (talk) during gameplay, informed the *Social Interaction* parameter in Saxe's model. This parameter will be discussed in more detail later, in the Methods of Analysis section (Section 3.5.2.3, p.74).

3.2.2.2 Prior understandings

A very important parameter that was expected to affect participants' goals was their prior understandings. Within this parameter, issues related to participants' previous knowledge and concepts are to be studied. As in Lave's (1988) 'supermarket mathematics', Noss, Hoyles and Pozzi (2002) 'nurse mathematics' and Noss and Hoyles' (1996b) 'bank mathematics' and as it is shown in previous research in *The Sims 2* digital game (Avraamidou et al., 2012) participants were expected to bring into their activity, concepts derived from their everyday life and from what they were taught in school. Vygotsky (1978) divided concepts into 'everyday' concepts - concepts that individuals form through empirical abstraction - and 'scientific' concepts - concepts that individuals form when interconnecting relating concepts[16].

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[16] Mitchelmore & White, (2007) offer a discussion on these concepts in relation to empirical and theoretical abstraction. Abstraction here is considered as one's awareness of similarities and relations between things and concepts, where new concepts (and

Davydov (1990), following Vygotsky, referred to 'empirical' and 'theoretical' thought. According to Davydov (1990), empirical thought is individuals' thought regarding relations of things they observe empirically in their reality whereas theoretical thought is individuals' attempts to reproduce reality (Hershkowitz, Schwarz & Dreyfus 2001). Since participants played a digital game which is a reproduction/representation of real life, it was expected to use prior understanding regarding i.e. the appearance that a typical house has, or that there is almost always a kitchen in a house. Such understandings are the *everyday prior understandings* parameter; understandings and concepts regarding real life. Since participants were asked to build houses, it was anticipated that processes related to mathematics would be employed, i.e. counting, area measurements, scientific knowledge regarding shapes and others (see Avraamidou, 2007). Such understandings are the *mathematical prior understandings* parameter. These two types of understandings informed the *Prior Understandings* parameter of Saxe's (1991) adapted model for this research.

3.2.2.3 Conventions / Artefacts

Apart from players' talk that was expected to occur during their interaction with each other, other important elements were expected to mediate participants' activity. Building on and expanding the adaptation of Saxe's model that I initially made during my MA dissertation (Avraamidou, 2007), the Conventions/Artefacts parameter was adapted to be composed of the following three elements: a. the *game's virtual artefacts*, which includes artefacts and rules created by the designers of the game, b. *players' virtual artefacts*, which includes the artefacts created by participants during their activity and c. *cultural conventions and artefacts* such as representations and conventions of the culture that players live in, which in this case was Cyprus' culture.

3.2.2.4 Activity Structures

In this parameter, Saxe (1991) refers to the whole cycle that the candy sellers needed to go through in order to complete their tasks; buy candies from providers, then sell

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knowledge) are built whilst consolidating old ones (see Davydov, 1990; Mitchelmore & White, 2007; Hershkowitz et al., 2001) but abstraction is not to be discussed here.

them to buyers and so on. In other words, Saxe referred to the actions that individuals needed to do in order to reach their objective: to sell their candies. This *Activity Structures* parameter has similarities with Leont'ev (1981) Activity, Action and Operation hierarchical distinction. In this research, this parameter refers to the paths that participants of this research followed in order to complete each activity (each task, each house). A cycle of participants' activity could be identified through patterns related to the way participants' actions progressed. For example, the results of the researcher's previous research (see Avraamidou et al., 2012) revealed a pattern of participant's behaviour during gameplay which led to the distinction of 42 episodes of his actions. The participant in that research first identified the problem (goal-initiation), planned the way to solve it (goal-process) and then acted to execute his plan (goal-ended). In this research, as it will be discussed later (Section 3.3.5, p.65), the two task-activities that players were asked to do, differed in terms of gameplay constraints and this affected the activity's structure. Nonetheless, patterns of the sequential emergence of participants' goal-directed Actions would be observed in this research as well.

The above diagram (Figure 3-1) concentrates the main theoretical ideas behind this research. However, as seen in my previous research (Avraamidou, 2007; Avraamidou et al., 2012) the goals that direct actions might in fact be interconnected and in order for one goal to be accomplished, several actions (which are directed by other goals) are required. Thus, it was important to collect rich data that would allow for multiple layers of analysis. I shall now describe and justify the selected methodology which I employed for this research.

3.3 Methodology

In this section I present and justify the methodology that I employed for this study, which is an embedded multiple – case study in Section 3.3.1. Next, I refer to the results of a pilot study I have conducted for this study in Section 3.3.2. Then in Section 3.3.3I present the sampling process and the participants of this study, which is followed by a description of the setting and context in Section 3.3.4 and participant's task in Section 3.3.5.

3.3.1 Embedded multiple-case study

Guided by the constructionist epistemology, theoretical perpective and the research questions underpinning this research, methodologies that could be applied here were qualitative methodologies, including, for example, ethnography, phenomenology and case study (Patton, 2002; Cohen et al., 2011). Phenomenology aims to study a phenomenon in individuals' lived experiences as they are immediately experienced (Husserl, 1998; Cresswell, 2007; Adams & van Manen, 2008). However, if phenomenology was to be used for this research, the focus would be on the phenomenon (lived experience) of playing a video game and not on the way individuals conceptualize their activity *whilst* playing the video game. Since this research aimed to explore meanings as made by individuals' through their activity, phenomenology and its variants are not appropriate.

Furthermore, ethnography is a methodology that aims in describing for example a group of individuals, a social group or an event in a classroom, focusing mostly on group's culture taking a holistic perspective (Fetterman, 2008). In the research field of digital games, ethnography is used in research investigating players' use and experience of digital games, such as Thornham's (2011) ethnographic account of household gaming experience and Salen's (2008) ethnographic approach to investigate a community that was created and ran by players of Civilization III digital game. Even though it was expected that patterns of interest would emerge in this study, the focus of this research was not to describe patterns of behaviour, values and beliefs of groups of children playing the video game. Although it was important to explore the way players' gameplay experience unfolded, focusing on what players-participants of this study thought of their gameplay experience would not help answering the research questions of this study. In this study, it was important to investigate other aspects such as players' intentions, goals, actions, interaction with each other and interaction with the game, in order to grasp fine details of players' mathematical thinking, acknowledging that each group of players might not have followed the same gameplay path. Therefore, it was important to capture players' onscreen activity using screen recording software. Thus, an ethnographic approach was not considered appropriate for this research..

The chosen methodological approach that met the research questions' needs for this research was case study because this would allow the collection of fine details of players' mathematical thinking within a particular real-life context. Creswell (2007, p. 73, emphasis of the original) defines a case study as an approach to explore "bounded systems … through detailed, in-depth data collection involving **multiple sources of information**". Furthermore, Yin (2009, p. 18) defines a case study as:

"an empirical inquiry that

- investigates a contemporary phenomenon in depth and within its real-life context, especially when
- the boundaries between phenomenon and context are not clearly evident"

As seen by the researcher's previous research (Avraamidou, 2007) the *boundaries* between participants' actions, mathematical meanings and thinking and, the context in which they were expected to occur in, were indeed not clear. Both Creswell and Yin highlight '*boundaries*' as an essential prerequisite for a study to be regarded as 'case' study and Yin goes further to state that these boundaries are not clearly marked. Stake (2000) on the other hand, highlights the importance of "bounding the case" (p. 448) under study and he suggests that researchers should identify the boundaries of the case when designing their research. Despite the fact that it is difficult to separate the case from the context and the surrounding in which it occurs, I shall try to 'bound' this case next.

In this research, the contemporary phenomenon of playing/interacting with a digital game was investigated in depth, within its *real-life context*; in participants' homes. As mentioned earlier, participants collaborated in groups of two in order to build the houses. Each group of two coeval children, working collaboratively while playing a digital game on their own computer, in their house[17] and not in a classroom, formed the (single) case study (Yin, 2009). However, I chose to have two groups of the same age range (two groups of 9-10 years old and two groups of 11-12 years old[18]) in order to establish that in case a group chose to withdraw, there would be a

[17] It is acknowledged that one of the two children did not eventually play in his/her own house, but in the other child's (friend) house.

[18] I shall justify this selection in the Participants' section that follows (Section 3.3.3)

satisfying number of participants. Therefore, the four groups of two were considered as a multiple-case study because and even though they differed in age, I followed the exact same research design procedures to acquire data from all four groups (Yin, 2009). In addition, I did not look at those case studies in a holistic view, as data could have revealed new pathways of data analysis and interpretation (Creswell, 2007; Yin, 2009). Thus, embedded ("multiple units of analysis", see Yin, 2009, p.46) multiple-case study, consisted of four single-case studies, was employed as the methodological approach of this research. At this point, it is important to state that I have conducted a pilot study in order to test and evaluate the methodology and methods I originally had in mind. I shall now briefly describe and discuss the pilot study.

3.3.2 Pilot Study

In January 2011 I conducted a pilot study to test the research design I had in mind. I will not expand on the results of the pilot study in this thesis. I will only focus on the methodological aspects of this pilot in order to aid discussion. The participants were two 16 year-old boys who were also friends. They played *The Sims 3* digital game (in Greek format, which was their native language) in one of the participant's house using the researcher's laptop. Their activity on the computer screen as well as their talk was recorded simultaneously using *Ambrosia's Snapz Pro X* Screen Recording Software (SRS) and was saved on the researcher's laptop. I was present in the house while they were playing the game but not in the same room. I only interfered when they called me for assistance regarding the game's features and at the beginning and ending of each session in order to initiate and terminate the recording. They created three houses overall; one with less budget constraints, one for a specific family with budget constraints and lastly they edited a house which was originally created by me. The aim behind the third house was for participants to attempt to solve a scenario-based problem, influenced by Guy Brousseau's puzzle (see, for more details, Appendix B, p.281). They had to build an upper floor for the existing house because, as I stated, the family wanted to create a guest house which needed to be the same as the original house, but smaller. In order to do so, the upper floor's two walls were already created, so participants had to figure out the ratio (7:4) and go on from there.

Overall, participants met three times (one meeting for each house) and played the game for approximately five hours. During their first meeting, the screen recording software recorded participants' activity on the computer screen but their talk was not recorded clearly because of the interference of the game's music. The settings of the screen recording software were changed during their second meeting, but there was no sound recorded. That was very unfortunate because I was not able to transcribe the data of the second session as I could not understand their actions, without listening to their talk. During the third meeting, both audio and visual data were recorded successfully. Data (of the third meeting) were transcribed using a three-columned Microsoft Word table (time interval, talk and description of activity, still image of the screenshot for that time interval).

The data collection process of the pilot study and the results of the informal analysis showed (amongst others) the following:

1. Participants seemed comfortable with each other (they were friends) and the context in which they were playing the game (in their own house).

2. Participants enjoyed playing the game but they felt that it was 'childish'. They preferred playing a different genre game. Therefore, younger ages might be more suitable for this research.

3. Simultaneously recording both audio and visual data of participants' activity was very important in order to be able to understand and further explore participants' activity.

4. The use of an existing mathematical puzzle as the scenario for the third house was not appropriate after all. Participants' talk revealed that they recognized that it was a 'mathematical problem', posed to them by someone else and they acted differently; the nature of their talk changed and more mathematical terminology was used. However, participants stated that they mostly enjoyed the building of the third house as it was more challenging, even though they knew that it was intentionally created by me and they did not solve the problem correctly after all.

5. The data transcription using a table was a good choice but there were several occurrences where the still images of their activity were not enough and I had to go back to the video format in order to understand their actions.

Following the above methodological conclusions from the pilot study, I shall now describe and justify the methodology and methods of this research.

3.3.3 Sampling and Participants

Random sampling was not appropriate for this research because it was vital that participants of this research were identified and recruited according to the following criteria: i. They must have used a computer before; ii. They must have never played *The Sims 3* digital game before but they would be interested to play it for this research; iii. Since they would work in groups of two, children in each group were require to approximately be of the same age, know each other and live in a distance less than 10km so that they could meet in each other's houses easily and feel more comfortable talking to each other; iv. They must have agreed to participate in the research and signed the participant's consent form (see Appendix C, p.282) and; v. Their parents must have agreed and signed the informed consent form (see Appendix C, p.284).

Due to the criteria described above, a form of convenience sampling was used. Children from the researcher's surrounding (i.e. family or friends' children) were firstly approached in order to establish that children felt comfortable with the researcher. Research investigating digital game integration in a classroom showed that boys showed positive attitudes in accepting the use of digital games in their classroom in comparison to girls because boys had more experience in playing digital games and in addition, not all game genres were appreciated by girls (Bonanno & Kommers, 2008; Bourgonjon et al., 2010). Nevertheless, Lynda Dyson, in Sudmann and Stockmann (2008, eds.) described the gameplay of teenage girls within *The Sims* digital game. In her observation, girls showed enthusiasm and appeared to be engaged in their activity of manipulating their virtual family in the game. Furthermore Gee and Hayes (2010) underline women's increasing interest of playing digital games such as *The Sims*. Thus, both boys and girls formed the participants of this study.

In addition, in my MA dissertation I had observed the activity of an 11 year-old boy whilst he was playing the English version of *The Sims* 2 digital game. The boy did not experience serious issues with the game or the language of the game. During his gameplay he appeared to be interested in this particular game context (see Avraamidou, 2007). However, the pilot study for this thesis, conducted in January of 2011, showed that 16 year-old children might not be appropriate. The participants of this pilot stated that even though they enjoyed playing the game, they would prefer playing a game of a different genre that did not feel 'childish'. I decided to select participants near the age of my MA because, based on anecdotal evidence from my MA dissertation research, that age (11 years old) appeared to enjoy playing this game. In addition, considering that almost half of the children between the ages of six to eight are exposed to and use digital technologies and play digital games on daily basis in the USA (Common Sense Media, 2011) I wanted to investigate the gameplay of younger players as well. Nonetheless, considering the gameplay difficulties that children below the age of eight might face due to the complexity of the particular game, for this study, I investigated the gameplay of Cypriot children, both boys and girls, within the age range of 8-12 years old.

Participants in this research were asked to build houses collaboratively, in groups of two. This was not a random choice. Rather, a couple of decades back, Barbieri and Light (1992) researched partners' interaction while working on problem-solving tasks. They concluded that the more the partners talked to each other about planning, negotiation and construction of knowledge, the more successful they were in solving the problems. Similarly, a few years later, Underwood and Underwood (1999) researched pairs of children working on a computer-based problem-solving activity where they found that the more children talked while working, the better their results in solving the problems. More recently, Howe et al. (2007) researched children's collaborative work in relation to achievement and they found that when children were working collaboratively, they achieved higher at school work in Science. Extending the results of Howe et al.'s (2007) research, Tolmie et al. (2010) reported possible relationships of cognitive and social gains of cooperative and collaborative learning. They measured work and play relations of groups of 12 to 14 year-old children at school and they concluded that collaborative work can have both cognitive and social impact on children. Even though, their research overrules the findings of MacDonald and Miell's (2000) study who found that good relations between group members, such as friendship, are a pre-condition for achievement, Tolmie et al (2010) reported that the fact that partners knew each other might "have been at most a matter of establishing sufficient minima to permit further growth as part of productive activity" (p.188). Therefore, it was aimed that participants within each group were friends of the same age, in order to increase participants' familiarity and help establishing productivity.

Therefore, four boys and four girls was a preferable sample. In order to establish comfort between participants, the following procedure for participants' recruitment was followed. For example, if child 'A' was participating, then the researcher asked for 'A' to name a friend, 'B', (preferably of the same gender and age and who lived in the same city) to play together. Then the parents of 'B' were approached and the researcher explained the research's aims and asked for their signed informed consent. In case B' parents did not agree for their child to participate in the research, then A would be asked to name another friend until A's friend and his/her parents agreed. This way, four children were contacted by the researcher, who in their turn chose four friends that were comfortable to play the game with. None of the participants withdrew from the study.

The participants of this research were: one group of two boys aged 8 ½ – 9 years old, one group of two girls aged 9 ½ years old, one group of two girls aged 12 years old and one group of a boy and a girl aged 12 years old. An overview of each group's meetings and duration of gameplay is presented below in Table 3-1. Each case study is sorted in the chronological order that data was collected. Pseudonyms were used instead of participants' real names. Marios and Christina's (M&C) and Alexia and Eleni's (A&E) gameplay data was collected within 2012. Stella and Katerina's (S&K) and George and Nikos' (G&N) gameplay data was collected within 2013. M&C and S&K groups needed an additional third meeting in order to finish their houses whereas A&E and G&N finished their houses during two meetings.

Case study	Participants pseudonyms	House	Meetings
1	Marios & Christina (12 years old)	Christina	3
2	Alexia & Eleni (12 years old)	Alexia	2
3	Stella & Katerina (9 ½ years old)	Stella	2
4	George & Nikos (8 ½ years old)	George	2

Table 3-1: Case studies overview

3.3.4 Setting and context

This research took place in Cyprus. Cyprus' context as the research context was not a random selection. Rather, it is the country in which I was born, educated and raised and am currently teaching and also the country that participants of this research live. As a Cypriot, I am familiar with Cyprus' context, society, culture and I am also a speaker of the native language. This familiarity could enhance the researcher's understanding of cultural issues affecting participants' interaction and talk. As a former student and a current elementary school teacher in Cyprus, I was able to gain an insider view of participants' mathematical thinking, because I am aware of the content of Cyprus Elementary Mathematics Curriculum and the status of mathematics that participants were estimated to have been taught in school, up to the time of data collection according to their age group. Nevertheless, it is acknowledged that this awareness is mostly theoretical, due to the limited years of teaching experience I had at the time. This allowed me to build an outsider's view and broaden the observation lenses and interpretation of participants' activity whilst analysing data.

3.3.5 Participants' task

All participants were asked to play the Greek version (native language) of the game and create two houses; one from scratch that was not indented for a specific Sims family (Task 1 – House 1) and one from scratch but after choosing a family from the game's family inventory (Task 2 – House 2). The rationale behind the first house was to let participants experiment with the content of the Build and Buy modes of the game and sense the affordances/limitations of the game, without specific budget constraints. During the construction of the second house, it was anticipated that participants would need to make decisions affected by the fact that the families would have specific budgets and needs which was something that was observed in my previous research of *The Sims 2* gameplay (Avraamidou et al., 2012). At this point, it is important to state that participants were informed regarding what they were asked to do in both tasks from the beginning of their gameplay.

As I explained earlier in the Introduction chapter, initially the design of this research included a third house which involved players editing a scenario-based virtual house in *The Sims 3* after they had finished with the first two houses. Although all groups went through this last activity of editing the third house, their gameplay activity for this house is not reported in this thesis because it was not analysed for two reasons. First, due to a technical issue one of the groups' data was inappropriate for analysis as there was no sound recorded during their third house activity. Second, considering that comparing the four groups' gameplay was important for this research, and due to the length of this thesis, I decided to concentrate on the – rich – results that were produced by the in-depth analysis that I conducted whilst analysing players' gameplay data during the first two houses, as they were enough to address the research questions of this thesis.

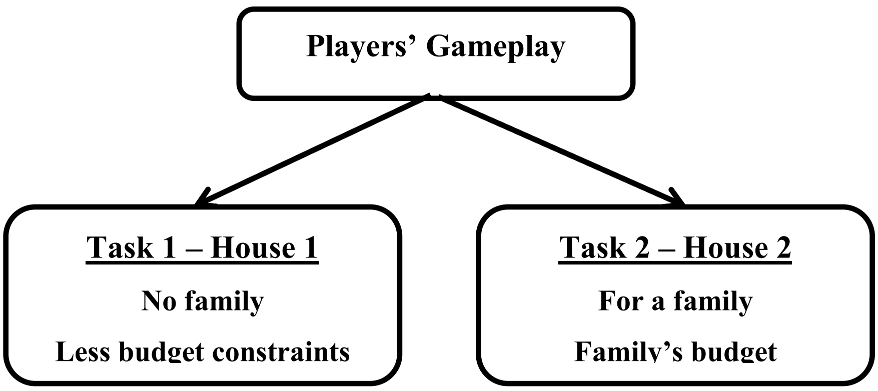


Figure 3-2: Players' gameplay – House 1 and House 2

Lastly, it was acknowledged that since participants were also players of this game, they could have followed different paths in order to build the two houses. Overall, all groups managed to create the two houses, explicitly stating that their houses were finished at the end of their gameplay. A more detailed report of the players' gameplay will be given in the Results chapters (Chapters 4 – 6).

3.4 Methods of data collection

Given the constructionist epistemology, the socio-cultural theoretical framework of this research and the qualitative nature of the research questions, the use of methods that would enable the continuous recording of participants' activity and discourse was essential. Questionnaires and interviews were not suitable methods for this research because such methods focus mostly on acquiring participants' beliefs, views, perspectives and opinions (Patton, 2002; Cohen et al., 2011). Rather, this research aimed to study participants' activity and goal-directed actions. Therefore, the most suitable method for the data collection of this research was (recorded) observation method because through observation it was possible to acquire rich audio and visual data of participants' actions (Spradley, 1980; Flick, 2002).

3.4.1 Observation – Screen recording software (audio-visual data)

Traditional uses of observation methods include researcher's observation/field notes and video recordings of participants. However, this method faced criticism in respect to researcher's involvement and intrusiveness due to the camera's and his/her presence during data collection (see Spradley, 1980). Nevertheless, "the effect of video becomes negligible in most situations after a certain phase of habituation" (Knoblauch, Schnettler & Raab, 2006, p.11) and the camera's intrusiveness gradually fades away. Furthermore, Emmison and Smith (2000, p.4) stated that visual data are not "what the camera can record but…what the eye can see". The above statement implies, that what the camera records is in fact what the lenses of the camera can capture and what the camera holder points to while moving the camera around. In addition, video recordings, especially when it comes to recording minors, raise ethical issues (Cohen et al., 2011). In this research video cameras in order to capture participants' gestures and moves was not used. This is mostly because of ethical issues, to reduce camera's intrusiveness effect and also because a video recording of a computer screen does not capture a high quality recording.

In this multiple case study, participants' activity was, mostly, on a computer screen. Recent technological developments allow computer users to record their computer screens using Screen Recording Software (SRS). Such software is very valuable to researchers because it provides them with new lenses in order to research digital worlds. Data captured from SRS, can allow researchers to study, for example, the way students interact with digital technologies (see for example, Watson, Mong & Harris', 2011 study), or the way they use Virtual Learning Environments in more depth. Researchers can also follow students' procedures to accomplish a computer-based task (see for example, Powell, Francisco & Maher, 2003), study computer-human interaction and evaluate ICT integration in more depth. Thus, in this research an SRS was used in order to record participants' Activity while playing the game on the computer. This software was *Ambrosia Snapz Pro X* (for Mac users). Given the theoretical framework of this research and the thesis' research questions, apart from participants' computer activity, their talk needed to be recorded as well. The above SRS allowed recordings of both visual (screen recording) and audio (sound recording) data simultaneously. This allowed for a rich audio-visual data collection of participants' Activity which could be replayed at any time.

3.4.1.1 Researcher's role

Spradley (1980) stated that the researcher's role during participant observation methods varies according to his/her involvement in the observed process. This variation lies along a continuum of being a complete observer towards being a complete participant (Gall, Borg & Gall, 1996). The initial intention was for me not to be present during participants' gameplay so that researcher's intrusiveness would be minimal. However, *The Sims 3* game is PEGI-rated as 12. This means that it is advised to be played by children aged 12 years old and older. In a correspondence with the PEGI committee I was told that the Build and Buy modes of the game are suitable for children under 12 years old. Nevertheless, the ethics committee of the University of Leeds required that and adult, the researcher, to be present during participants' gameplay in order to make sure that participants will not play the other modes of the game. Therefore, the researcher needed to be in the same room, monitoring participants' activity. My role, as the researcher, was therefore an observer as participant (Gall et al., 1996). This means that I was in the same room, observing participants' activity and assisting them in technical issues that had to do with using the game. However, I did not interfere with participants' activity or decisions during gameplay unless I was asked by the players.

3.4.1.2 Researcher's observation/reflection notes

In order to minimize participants discomfort I did not keep any observation notes while participants were playing the game. The SRS recorded participants' talk and cursor moves on the computer screen. Nevertheless, the fact that I was present during game play allowed me to observe aspects of participants' activity that the SRS did not capture, such as signs of participants' discomfort, gestures and feelings while playing the game. Thus, after each meeting I kept a reflection observation diary where I kept notes regarding participants' activity. Also, I described the physical context of the data collection, for example, the room where participants played the game in, as this is important when conducting a case study (Merriam, 2002; Yin, 2009). These notes were not highly structured as there were aimed to be mostly complementary to the main observational data and there were not as detailed as field notes. Lastly, it is worth mentioning that details regarding participants' demographics (age, sex, town and computer novelty) were gathered before the data collection according to the criteria described earlier (see Section 3.3.3). The data collection resulted in, overall, 9 videos of data as presented in Table 3-2 below:

Case study	**Participants pseudonyms**	**House**	**Meetings**	**Recordings length (hr/min)**	**Total length (hr/min)**
1	Marios & Christina (12 years old)	Christina	3	2:04 -1:51 - 1:52	**5:47**
2	Alexia & Eleni (12 years old)	Alexia	2	2:10 - 1:36	**3:46**
3	Stella & Katerina (9.5 years old)	Stella	2	1:40 - 3:15	**4:55**
4	George & Nikos (8.5 – 9 years old)	George	2	1:39 - 1:22	**3:01**

Table 3-2: Participants' gameplay recordings

At this point, it is important to highlight certain limitations that I have identified because of the methodological selections I made whilst designing this research. I recognise that the choice of an embedded multiple case-study would not allow for an in-depth understanding of the players-participants' gameplay experience, pleasure, feelings and game appreciation. However, this was not the focus of this research and the research questions of this study required the collection of fine details of players' goal-directed actions and mathematical thinking within a certain bounded system, such as the context of playing a digital game in out-of-school settings. In addition, as a digital game, *The Sims* 3 is designed to be played in a single-player mode but it was decided to have players playing this game in groups of two. Even though I acknwledged that this might have affected their gameplay, nonetheless, it was essential for this research to ensure that participants would share their thoughts through their talk so as to conduct an in-depth analysis of their goals and actions without having the researcher interfering with interview-like questions. Lastly, due to ethical issues (see Section 3.7, in p.86), it was inevitable that the researcher was to be present in the room whilst players were building the virtual houses and it was acknowledged that this might have affected their gameplay.

3.5 Methods of data analysis

Once data are recorded, the researcher might employ several methods to first transcribe and later analyse the data to answer the research's questions. The researcher needs to be aware of the kind of analysis s/he is going to employ in order to select an optimal transcription template (Cohen et al., 2011; Ryan & Bernard, 2000). In this research, data were audio-visual. The most common way of manipulating audio and visual data is by transcribing them into textual data. This is often done using tables where participants' talk and a written description of their activity are aligned chronologically in respect to a 'duration' column and this table is usually accompanied by screenshots from the video recordings (see for example Pirie's, 2001, p.348, *"time activity trace"* technique and Edwards & Lampert, 1993). However, care should be taken when treating audio-visual data as textual data. Such data transformation might reduce data's richness because data's screenshots and written descriptions might not enclose the actual video recording's multimodality (Dicks, Soyinka & Coffey, 2006). For this reason, I transcribed participants' talk (in native language) as it occurred, marked the duration and timing of the video data and saved some screenshots of the status of their activity.

3.5.1 Data transcription

For this research's analysis, I used Microsoft Word and Microsoft Excel in order to transcribe and analyse the data. In this research, participants spoke Greek. To transcribe the data I used the transcription template shown in Table **3-3** below (set as an example). Data were transcribed chronologically, using the *Time* column. Whilst replaying the video data of each group, I transcribed participants' talk in the original language (Greek) to avoid translation misinterpretations and also wrote descriptive accounts of participants' actions in the *Talk and description of actions* column. Participants' talk was transcribed word for word, exactly as it was spoken. However, I did not transcribe background noise or other sounds apart from participants' talk. I then added the *Screenshots* column in order to have some visual data for those instances.

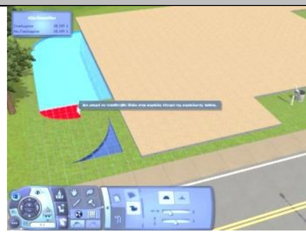
Time intervals	Talk and description of actions	Screenshots
25:15 – 25:26	**C:** No, we should do it like this. It is nice to have a curve, it's uncommon. **M:** OK, I think we should delete a part of it because it's too elongated. **C:** OK	

Table 3-3: Participants' talk and description of actions transcription template

Whilst transcribing the data, I used standard punctuation to present participants' talk and I distinguished the textual description of their activity in brackets. Additionally, I marked bold any words that were spoken emphatically and in case participants' talk overlapped I clarified that as well.

3.5.2 Stages of analysis

Given the qualitative and exploratory nature of this research questions and the socio-cultural theoretical framework of this study, the analysis was conducted in six stages. For each stage of analysis, each case study was analysed in the chronological order of data collection.

3.5.2.1 First stage analysis – Open coding

The first stage of this research's analysis aimed in describing participants' actions during their gameplay. This was done by producing open codes *à la* Strauss and Corbin (1998). Going through the textual data transcriptions, I coded each group's overall activity by highlighting and characterizing – using phrases – the group's actions. This was done by colouring the print textual data using colour pencils, whilst keeping a list of the codes and the colour that was assigned to that code on a separate paper. In addition, for each code the number of occurrence was also kept for each group. The open codes that were produced by the data of Case Study 1 (Christina & Marios) were used to code the data of the rest of the cases. In case there were additional codes occurring during the coding of the other cases, these were added to the list.

When the coding process was finished, I reviewed the codes and grouped them into thematically shaped categories. For example, the four codes shown in Table 3-4 below were grouped into the category "experiencing the reality of the game". This table was created in MS Excel and each code entry was marked by the case's name (i.e. SK – for Stella and Katerina), the House they were building when the code appeared (i.e. SK*1* – for House 1 with no budget constraints) and then the page of the transcriptions that the code occurred (i.e. SK1-*20* – for page number).

Category	**1. Experiencing the reality of the game**			
Code	1.1 Considerations about the virtual characters in *The Sims* (i.e. Sims family)	1.2 Accessibility and usability of the house	1.3 Reference to real-life houses' structure and appearance (culture and everyday experience)	1.4 Considerations regarding Sims family's safety and privacy
Case (Name/ House – page of transcription)	SK1 - 20	GN1 - 21	SK1 - 6	SK2 – 18
	SK2 - 20	GN1 - 24	SK1 - 52	SK2 – 49
	SK2 - 44	GN2 - 29	SK1 - 54	SK2 – 56
	…	…	…	…

Table 3-4: First stage of analysis - Open codes example (Category 1)

This kind of mapping was chosen for easy access to the exact instance where the code appeared and also to provide information in respect to the frequency of occurrence of a certain code within a case, the frequency of occurrence in a house and also the frequency of occurrence of that code in all cases (see Chapter 5, Section 5.1.2, p.125). The open codes and the categories of the first stage analysis provided a valuable overview of what happened in the four cases and what appeared to be important in each case.

3.5.2.2 Second stage analysis – A descriptive account of what players did

Getting an overview of what happened during the gameplay of the four cases was not enough. Participants' actions needed to be analysed. This stage of analysis was influenced by Saxe's emergent goal component. In order to investigate the nature of participants' goal-directed actions, I needed to identify participants' goals during their activity. Their goals were revealed through their talk, when they explicitly discussed their next actions or were implied by the sequence of their actions (see Avraamidou et al., 2012) as I reviewed each case study's video recording. Going through each group's transcriptions, I asked the questions "What did they do?" and "Why did they do it?" in order to identify their Actions and the goals that directed those actions respectively. Every identified Action and goal was numbered and linked to the transcriptions that they were related to using a MS Word table (Table 3-5).

Time / Transc.	Goal	Action
p. 8-10 (26:12 – 28:35)	103. Choose a coffee table (design and colour) from the menu	They click on the tables' menu and agree on a style and colour of a table
	104. Rearrange the sofas/couches so as to add another coffee table between them	They move the sofas and the couches in a way that another coffee table can be added between them
	105. Place another coffee table (bigger) in front of the couches	They select an additional coffee table from the menu (bigger one) and add it in the space they had created between the sofas and the couches

Table 3-5: Second stage analysis I – Goals and actions (S&K, House 1 example)

This resulted in a sequence of actions and goals that summarized participants' activity. Nonetheless, most of the goals were connected to each other because they emerged whilst other goals were being processed by the groups. Thus, the goals were reviewed once again and were grouped into "Major" goals and "Sub-goals" (See Table 3-6 below) as follows:

- *Major goals* were the goals that directed participants' actions during their gameplay. These goals were either stated explicitly by players or were identified through their actions with the question: *What do players intend/want to do?*
- *Sub-goals* were goals that also directed group's actions but were 'must do' things that came into being and emerged while players were working on a previously set goal. They served as "means to ends" to that "major" goal. These sub-goals were either stated explicitly by players or were identified through their actions with the question: *What do players need to do?*

Time / Transc.	Goal (major)	Sub-goal
p. 8-10 (26:12 – 28:35)	38. Add coffee tables in the living room	103. Choose a coffee table (design and colour) from the menu
		104. Rearrange the sofas/couches so as to add another coffee table between them
		105. Place another coffee table (bigger) in front of the couches

Table 3-6: Second stage analysis II – Major goals & sub-goals

This grouping resulted in a sequential account of the way *major goals* and *sub-goals* interconnected, providing information regarding participants' sequence of actions and in addition, the complexity of some of the *major goals*. However, it was important to examine more closely the way those goals were initiated and processed during the each group's gameplay.

3.5.2.3 Third stage analysis – Major goals, sub-goals and Saxe's model

As explained above, sub-goals were goals that emerged during participants' gameplay. In order to analyse how they were initiated and processed, Saxe's four-parameter modified model was used (see Section 3.2.2, p.53). In addition to the initial table, three more columns were added (*Initiated by*, *Processed by* and *Achieved*) in order to code the parameters that initiated those goals and the parameters that affected the way they were processed by the players in order to achieve them (or not) as shown in Table 3-7 below.

Time / Transc.	Goal (major)	Sub-goal	Initiated by	Processed by	Achieved?
00:00 – 02:00 (p. 1-2)	1. Goal	1. Sub-goal	Player's initial GVA PVA CCA GR MU EU GU	GVA PVA CCA GR MU EU GU	Yes Paused Abandoned

Table 3-7: Third stage analysis I– Goals initiation and process coding (example)

Following Saxe's model, two of the four parameters were used in order to code the way goals were initiated and processed during gameplay; Prior Understandings and Conventions Artefacts. Following the modifications made to the model (see p.) the codes that appear in Table 3-7 above are abbreviations of the categories related to each parameter. Table 3-8 below further explains the way each of those codes was perceived in this research, providing also an example. An earlier version of Table 3-8 was used during the inter-coder reliability session and was finalized in Table 3-8 form afterwards (see Section 3.6.1, p.83).

Parameter	Code	Description	Example
Conventions / Artefacts	**GVA**	**Game's Virtual Artefacts:** The game's (default) available virtual artefacts/objects which are available to players for edit/use and affect their gameplay, such as game's menu and menu items such as furniture, tiles, appliances, Sims families, maps, plot areas and so on.	The menu that list the available doors that players can choose of.
	GR	**Game Restrictions:** Rules and restrictions appearing in the game during gameplay and affect players' gameplay. This might include game's pop-up messages regarding errors, budget issues-red options and other game restrictions of players' actions.	The game does not allow players to add a door when it is not supported by a wall (shows error message and marks the door with red colour).

	PVA	**Players' Virtual Artefacts:** Particular artefacts that are created by the players during gameplay and affect their gameplay.	A specific pattern that was created with different tiles for a room's floor decoration.
	CCA	**Cultural Conventions and Artefacts:** Representations / conventions of culture	For example the game's currency, buy/sell and so on.
Prior Understanding	**MU**	**Mathematical Prior Understandings**: Mathematics-related prior understandings that players bring into the gameplay which can both constrain and enable their goals, such as algebra, geometry prior understandings and so on.	A 350s bed is a cheaper choice than a 1500s bed.
	EU	**Everyday Prior Understandings**: Prior understandings related to everyday life, that players bring into the gameplay which can both constrain and enable their goals, such as the way a house looks like, the content of a specific room and so on.	A fridge and an oven are placed in the kitchen whereas a bed is placed in the bedroom.
	GU	**Game Prior Understandings**: Players' prior understandings that are associated with the gameplay of this particular game and refer to previously experienced gameplay of this particular game.	The doors can be found in the "door submenu". In order to add a door you first need to have placed a wall to attach it to it.

Table 3-8: Third stage analysis – Saxe's modified emergent goal parameters coding

Thus, for each sub-goal (and sometimes major goals), the codes (and usually a combination of the codes) explained in Table 3-8 were used in order to describe the way those goals were initiated and processed. In addition, the achievement of those goals was marked in the "Achieved" column using the following codes:

- *Yes:* There was an 'end product' as a result of that 'major' goal and/or sub-goals achievement, players explicitly stated that they are satisfied with the outcome and proceed with setting a new 'major' goal.
- *Abandoned:* Players explicitly decided to abandon that goal and proceed without achieving the specific goal.
- *Paused:* Players explicitly decided to move on to a different goal and return to the specific major/sub-goal later (and they did).

As explained earlier, participants' talk formed the Social Interaction parameter of Saxe's modified model and the way this parameter was coded is explained next.

3.5.2.4 Fourth stage analysis – Socio-cultural talk analysis

As a fourth stage, participants' talk (of each case study) was analysed. In their research project exploring children's talk in problem-solving activities, Fisher (1992) and Mercer (1995; 2005) classified three types of talk (or "social modes of thinking", Wegerif & Mercer, 1997, p.53) occurring while members of groups in schools were working on computer-based tasks; *Disputational, Cumulative* and *Exploratory Talk*. According to them, *Disputational* is the kind of talk that members of a group use when they make decisions individually by disagreeing with other members' ideas without providing any justifications to support their disagreement. *Cumulative Talk* is identified when members are positively, yet uncritically, building on each other's ideas and *Exploratory Talk* is when the members of the group view critically each other's ideas and opinions, accepting or challenging them by justifying their final decision as a group (Mercer, 2010). According to Mercer (2010), when using *Exploratory Talk*, knowledge and reasoning become more visible. This fit well with the constructionist epistemology and socio-cultural framework of this research. The nature of participants' collaboration was characterized by those three types of talk. Specifically, for each goal (major and/or sub-goal) of the players another column, *Talk*, was added to the initial Table 3-6 which included the type of talk participants shared during that specific time as shown in Table 3-9 below.

Time / Transc.	Goal (major)	Sub-goal	Talk	Initiated by	Processed by	Achieved?
00:00 – 02:00 (p. 1-2)	1. Goal	1. Sub-goal	**EXPL** **CUM** **DISP** **(Combinations)**	Player GVA PVA CCA GR MU EU GU	GVA PVA CCA GR MU EU GU	Yes No Paused Abandoned

Table 3-9: Fourth stage of analysis – Types of talk

3.5.2.5 Fifth stage analysis – Identifying mathematics and mathematical thinking

The results of previous stages of analysis were analysed again in order to detect mathematics related elements that occurred. The first stage's open codes and categories provided a first detection of players' actions which were – visibly (Noss et al., 1996) – mathematics related. The second stage of analysis provided a sequential account of players' gameplay actions and the codes and in combination with the third stage of analysis, mathematics related actions could be identified through the MU code that was used for coding the major goals and sub-goals. Since data were finally mapped in Table 3-9, those MU codes were also coded in combination with the type of talk that players' used during that specific major goal or sub-goal gameplay.

Thus, as a fifth stage of analysis, the major goals and sub-goals of each group that were marked with MU code (either in initiation or processing column, Table 3-9), were isolated. Then, each gameplay extract that was connected to those sub-goals was examined closely and the area of mathematics that was involved in each one was coded using open codes. This was conducted either by highlighting in each MU coded extract, phrases in players' talk in which a mathematics-related area was used or by analysing players' actions (description of the action, if there was not verbal talk). For example, when players were comparing the cost of two items and explicitly stated phrases such as "cheaper / more expensive", I coded this as "cost (compare)"[19]. Overall, the open codes that occurred were: *arrangement (placement)*, *budget*, *cost (compare)*, *pattern*, *rotation*, *shape, size, space (area),* and *'the same' ('look right')*. Those MU open codes provided an overview of the mathematics' ideas that were involved in each groups' gameplay. Returning to the operational definition of mathematical thinking that was provided earlier in this study (see p. 43), numerical and arithmetic (comparing costs, pattern, budget) and geometric (shape, rotation, space (area), 'the same') relationships were explored by players during their gameplay. . Nonetheless, the frequency of occurrence of each open code was marked separately in each house they were building, as it was important to explore the differences in a less constrained and in a constrained gameplay.

Lastly, major goals and sub-goals that were coded with MU were also analysed in terms of the type of talk that was used and vice versa; the number of *Disputational*, *Cumulative* and Exploratory type of talk involved MU codes for each group's major goals and sub-goals initiation and processing. This was done in order to investigate whether their gameplay actions which involved prior mathematical understandings (MU) were linked to *Exploratory Talk* in respect to their less constrained and their constrained gameplay.

3.5.2.6 Sixth stage analysis – Comparing cases

Even though the small number of cases and the diversity of participants do not allow for generalizations (Cohen et al., 2011), I conducted a cross-case analysis in order to detect similarities and differences between the four cases (Yin, 2009). During the sixth stage of analysis emphasis was given on the way participants carried out the two Activities; the procedures of constructing and reconstructing the two houses. This means that comparisons across cases were made, focusing on a macro perspective. Goals, Actions and Sub-Goals of each case were compared. In order to do so, the results' tables of the four groups that were produced during the second, third and fourth stages of analysis were compared. This study did not aim to make generalizations regarding the way children proceeded to accomplish the two houses. Nevertheless, comparing data from all cases provided a greater understanding of the

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[19] A more detailed presentation of the open-codes that occurred in the fifth stage of analysis is provided in Chapter 6 (Section 6.1.2.1, p.158)

structure of each group's Activity and helped the identification of gameplay patterns.

At this point, it is important to summarise the research design of this research in order to map the methods of data collection and data analysis to the research questions. The theoretical framework informing this research is socio-cultural, adapting ideas from Activity Theory, socio-cultural theories of mediated activity and constructionist epistemology. Earlier, I have stated that the unit of analysis for this research was the players' goal-directed Actions. I have highlighted the importance of identifying and studying individuals' goals because within those goals, their mathematical thinking was expected to be revealed. As explained earlier, participants' mathematical thinking is shaped by previous understandings, mediational tools and social interaction. The main method for collecting data was observation and data were recorded using a Screen Recording Software which is able to record both audio data (participants' talk) and visual data (participants' activity on the computer screen) simultaneously. I needed to monitor participants' gameplay due to ethical reasons and I was an observer as participant, but did not interfere with participants' actions or decision making. Given that I was present during data collection, casual observation/reflection notes were also recorded and were used as supplementary data.

Furthermore, the six stages of analysis were conducted in order to provide answers to the major research question and the four research sub-questions. The stages worked together in order to help me make interpretations regarding players' gameplay, mathematical thinking and players' interaction with each other and the game's artefacts. For example, the coding analysis conducted during the third stage of analysis allowed me to later on focus on the mathematical aspect by revisiting MU-coded parts of players' gameplay for further analysis during the fifth stage of analysis. As explained earlier, each stage of analysis fulfilled a specific purpose and was connected to specific research sub-questions of this research as shown in Table 3-10 below.

<table>
<tr><th>Epistemology</th><th>Theoretical Perspective</th><th>Methodology</th><th>Methods</th><th>Analysis stages</th></tr>
<tr><td>Constructionism</td><td>Elements from:
• Activity Theory
• Saxe (1991) socio-cultural model of emerged goals (adapted model)</td><td>Embedded-multiple case study consisted out of 4 single case studies.

<u>Participants:</u>
- two 9 ½ year-old girls
- two 8 ½ year-old boys
- two 12 year-old girls
- one 12 year-old girl and one 12 year-old boy</td><td>- Observation through screen recording software (audiovisual data)
- Researcher in the same room
- Researcher's reflection notes</td><td>1. Open coding (RsQ[20]: 1, 2, 3)
2. Goal and sub-goal directed Actions (Saxe's emergent goals) (RsQ: 4)
3. Major goals, Sub-goals and Saxe's parameters (RsQ: 1,4)
4. Socio-cultural talk analysis (RsQ: 3)
5. Identifying the mathematics and mathematical thinking (RsQ: 1, 2)
6. Cross-case analysis (RsQ: 1, 2, 3, 4)</td></tr>
</table>

Table 3-10: Summary of the research design of this research

20 RsQ: Research Sub-Questions

3.6 Reliability and validity

Establishing reliability and validity when conducting a research project, is often an essential part of it (Creswell, 2007). Research is reliable when another researcher can later follow the same procedures of the original research and get the same results (Yin, 2009). Miller (2008, p. 910) states that: "Validity of all research is heightened by ensuring that research procedures remain coherent and transparent, research results are evident, and research conclusions are convincing". Nevertheless, as Ridgway (1988) claims, within qualitative research, validity and reliability are mostly intertwined because the one is often an inherent of the other. In this research, the same data collection procedures were followed in order to collect data that formed the four cases. In addition, the same transcription and analysis protocols were followed in order to transcribe and analyse data for the four cases. This minimized errors and ensured internal validity (Yin, 2009). Furthermore, in all stages of analysis I used tables produced in MS Excel and MS Word in order to organize, code and link the transcribed data with the exact timeframes of the audiovisual recordings. This minimized researcher's bias and early interpretations during the transcription of data (Dicks et al., 2006).

Lastly, selected data transcriptions were used in order to establish inter coder reliability (Tinsley & Weiss, 2000). The selected data transcriptions and a two-paged text describing the analysis procedures and coding was given to Dr. Eleni Demosthenous. Eleni is a recent PhD graduate of the University of Cambridge whose research is related to Mathematics Education and is also a native speaker of the language that participants' used. Eleni had first become aware of the overall scope of my research when we both participated in the 6th YERME Summer School, in 2012. Since then we occasionally meet and discuss research related matters and sometimes our PhD research. Even though Eleni was aware of my overall theoretical framework, she had never coded any of my research's data up to the day I asked her to be the inter-coder researcher for my study.

3.6.1 Inter coder reliability

In order to check the reliability of the coding schema that I had developed and applied during the analysis of the data, Eleni and I had a meeting that lasted approximately three (3) hours. The meeting took place right after I had finished the first four stages of the data analysis for all groups. During the meeting, Eleni was first given to study a print copy of Table 3-8 and Table 3-9 that were presented earlier in the stages of analysis. In addition, Eleni was given a page of brief definitions of major goals, sub-goals, *Cumulative*, *Disputational* and *Exploratory Talk*, similar to the ones illustrated in Sections 3.5.2.3 and 3.5.2.4 earlier. Eleni studied the tables and definitions and when she confirmed that she had understood the codes she was given a table that presented the coding I had already made for a specific 9-minute episode of Stella and Katerina's gameplay, following Table 3-9's structure. This extract was chosen because it involved almost all codes (except from *Disputational Talk* and Game Prior Understanding). In addition, the respective audiovisual data extract was available to Eleni for replay and the respective data transcriptions in print. Eleni read the ready-made table of codes and she was rewinding the video data and reading the data transcriptions several times, whilst marking the codes of the table that she accepted. Eleni circled two codes that she did not understand; PVA and CCA. She said that she could not see the difference between them. Thus, I discussed and explained the two codes to her and she understood the difference but suggested that I should rewrite the definitions of the two codes in Table 3-8 to make it clearer, which I did.

Next, I asked Eleni to code, alone, a 6-minute extract of Stella and Katerina's gameplay, from House 1 gameplay, using the coding schema. The specific extract was the creation of the dining room area of the first house that occurred right before adding the dining tables, which was the 9-minute extract that was given as an example. It was selected because it involved actions related to the same room of the house. Whilst coding this extract, Eleni had available:

- Table 3-8, Table 3-9 and the definitions of the codes
- A transcription of players' talk during that 6-minute extract
- The 6-minute extract of audiovisual data (video)

- An empty version of Table 3-9 for her to fill in during coding

Eleni viewed and listened to the audiovisual data once, then rewound it and replayed it intermittently whilst noting the ‘major’ goal and sub-goals. Eleni asked to compare the goals before proceeding with the rest of the coding. We compared them and apart from some differences in wording, the main essence of those ‘major’ goals and sub-goals was the same. Eleni then coded the type of talk, the initiation and processing of the major goal and sub-goals and whether the goals were achieved.

Figure 3-3 below shows a comparative table of my coding (Andry) and Eleni’s coding of this 6-minute extract. The columns in grey colour show my coding and the columns in white colour shows Eleni’s coding. As can be seen by Figure 3-3 Eleni missed three codes that I had marked the specific extract (shown in a red colour). However, overall, I used 25 codes in my coding whereas Eleni used 22 (Table 3-11). The percentage of our coding agreement was 88% (=22/25*100%).

	Codes	**Researcher**	**Eleni**
Conventions / Artefacts	GVA	**4**	**2**
	GR	2	2
	PVA	**3**	**2**
	CCA	0	0
Prior Understandings	MU	2	2
	EU	7	7
	GU	1	1
Players	K	2	2
	S	4	4
Type of Talk	DISP	0	0
	CUM	3	3
	EXPL	2	2
	CUM/EXPL	1	1
Total		**25**	**22**

Table 3-11: Comparison of frequency of code entries (Researcher and Eleni)

Nonetheless, as shown in Figure 3-3, the only difference in our coding was the three codes that Eleni had missed; 2 GVA and 1 PVA codes. Following a discussion where I explained why I coded those 3 codes at those moments, Eleni agreed with my coding and she said that this was because she was confused with the definition of GVA and PVA and I should clarify them in the final version (Table 3-8).

House 1 - Stella and Katerina – Create the dining room (Intercoder reliability)

A. Timeframe	B. Goals ('major')	C. Sub-goals	D. Type of talk Andry	D. Type of talk Eleni	E. Initiated by Andry	E. Initiated by Eleni	F. Processed by Andry	F. Processed by Eleni	G. Achieved? Andry	G. Achieved? Eleni
p. 8-10 (25:20 - 31:33)	1. To create the dining room	None	None	None	K GVA (menu)	K	None None	None None	Paused (see Goal 3)	Paused (see Goal 3)
	2. Add coffee tables in the living room area	2.1. Choose a coffee table (design and colour) from the menu	CUM	CUM	S GVA	S GVA	EU	EU	YES	YES
		2.2. Rearrange sofas and couches so as to place the coffee tables	CUM	CUM	S EU PVA	S EU	EU MU	EU MU		
		2.3. Place another coffee table (bigger) in front of the couches	CUM	CUM	GVA	GVA	EU/GR/GVA	EU/GR		
	3. To create the dining room (see goal 1)	3.1 Decide where to create the dining room	EXPL	EXPL	S (continue goal 1)	S (continue goal 1)	EU PVA	EU PVA	YES (linked to goal 1)	YES (linked to goal 1)
		3.2 Add the walls to create the room	EXPL	EXPL	S	S	GR EU	GR EU	YES	YES
		3.3. Reform the walls so as to create an uncommon ("παράξενο") shaped dining room area like they did with their bedroom's walls	CUM / EXPL (?)	CUM / EXPL (?)	K PVA	K PVA	GU EU MU	GU EU MU		

Figure 3-3: A comparative table of the researcher's (Andry) and Eleni's coding on the same data extract

3.7 Ethical issues

The research design of this research was approved by the University of Leeds Ethics Committee (see Appendix C, p.289). I have discussed possible ethical issues in the application submitted to the committee and appropriate changes were made. Participants of this research were children under 12 years old that were asked to play a game that is PEGI rated as 12 (advised to be played by 12 years and older). As explained earlier, I needed to be in the same room with participants. It was acknowledged that my presence there might have resulted to the observer's effect (Spradley, 1980). Thus, I was particularly careful to make sure that participants felt comfortable with me before participating in this research. As required by the regulations, both participants and their parents signed an informed consent form before participating in this research. Parents were informed regarding the general scope of this research and the exact procedures that their children would follow while participating, as well as the way and the reasons why their children needed to be recorded (see Information Sheet in Appendix C, p.285). Then, they were asked to sign an informed consent form (see Appendix C, p.284). Even though children were minors, I provided them with an informed assent form as well, which they needed to sign (see Appendix C, p.282). I aurally informed both participants and their parents of the research's procedures. However, I did not reveal the research's aims to participants, as this might have hindered participants' behaviours during data collection (Cohen et al., 2011). Nevertheless, I informed participants about the research's aims after the data collection was completed. It is important to mention that participants' data were confidential and they were given pseudonyms and only I, the researcher, know the association with their real names. Data were encrypted and were kept in an encrypted hard drive.

Part II: Results and Findings

Chapter 4 Description of the four cases

The Results part of this thesis includes three chapters; *Chapter 4 – Description of the four cases*, *Chapter 5 – Gameplay, goals, actions and talk* and *Chapter 6 – Episodes of interest*. Each chapter is written and presented in a way to help the reader go through the results that derived from the six stages of analysis (See Section 3.5.2, p. 71), starting with an overview of the players and their artefacts in this chapter, then focusing on specific results related to the players' gameplay, goals, actions and their talk in Chapter 5 and lastly presenting episodes of interest related to the research questions in Chapter 6 in preparation for the Discussion chapter.

This chapter's aim is twofold; first, it introduces the four case studies of this research by presenting the players who participated in this research and by providing an overview of the two houses they created during their gameplay and second it provides further information regarding *The Sims 3* so as to help the reader understand the game content, menu and gameplay. There are five sections in this chapter. The first four sections present the case studies in the chronological order that this research's data were collected; Case study 1 – Marios and Christina (Section 4.1), Case study 2 – Alexia and Eleni (Section 4.2), Case study 3 – George and Nikos (Section 4.3) and Case study 4 – Stella and Katerina (4.4). Lastly, in the fifth section (Section 4.5) a brief summary of the four groups is provided in order to connect this chapter to Chapter 5 that follows.

4.1 Case study 1: Marios and Christina

Marios and Christina (M&C) are 12 years old (Year 6) and they live in a suburban area in Larnaca. They have been friends since kindergarten, they go to the same school and they said that they meet and play almost daily during summer time because they live close to each other and their parents are friends. Neither of them has played *The Sims* series before. Nonetheless, during data collection, Christina mentioned that she had heard of the game before through one of her friends who is a Sims player. She said that she did not play the game herself but was aware of the game's aims. During their third meeting, M&C talked about buying the game. In addition, during their third meeting, they mentioned that they were aware of a keyboard cheat that players use in order to increase the budget in *The Sims 3* game, which they searched the internet for. However they did not cheat in their gameplay.

A general comment on Marios and Christina's interaction during their gameplay is that at the beginning (first meeting), Christina appeared to be more in control of their gameplay. Even though they both had almost equal time controlling the mouse, Christina was the one sharing her opinion a lot more than Marios. In fact, there were times where Christina was not even asking for Marios' opinion. Rather she was stating what their next move was going to be and Marios mostly replied with a "Yes" to Christina's suggestions or remained silent. However, towards the end of the first meeting and especially during the next two meetings, in which they were building the budget-constrained house for the family, Marios begun sharing his opinion more often and spoke up when he did not agree with Christina's suggestions. This allowed them to express their rationale before acting.

4.1.1 Description of M&C's Houses

M&C built the two houses in a total of 5 hours and 47 minutes of gameplay, in 3 meetings. As shown in Table 4-1, they spent 3 hours and 49 minutes of their total gameplay to build House 1 (less budget constraints) and 1 hour and 45 minutes to build House 2 (for a family, with budget constraints). However, they created and furnished the ground floor of House 1, then proceeded with the building of House 2 during the 2nd and 3rd meeting and then returned back to House 1 to furnish the upper floor after they had finished House 2.

	Gameplay time (h)	Furnished lot value	Unfurnished lot value	Initial budget	Final budget
House 1	3:49	§[1]224023	§86388	-	-
House 2	1:45	§17491	§15508	§20125	§9

Table 4-1: M&C overview of Houses 1 and 2

[1] § - Simoleons: the game's currency symbol

When players are in the Build mode of the game, a box appears on the top left corner of the screen (Figure 4-1) that indicates the value of the lot without any furniture/appliances (*unfurnished lot value*) and the value of the lot with all furniture/appliances (*furnished lot value*). It is worth mentioning here that menu items that can be found in the Build mode of the game are included in the *unfurnished lot value* sum and menu items that can be found in the Buy mode are included in the *furnished lot value* sum. However, it was noticed by the researcher that items that appear in both modes, such as wallpapers can change the value in both Furnished and Unfurnished value sums.

The final *unfurnished lot value* of House 1 was §86388, whereas the *furnished lot value* was §224023, almost three times the *unfurnished lot value* (Table 4-1). This means that players created a house, the furniture and appliances of which had an overall high value. For House 2, Marios and Christina had to create a house for a family with a total of §20125 available budget to spend for buying a lot and building a house. When they finished House 2, the family's budget balance was §9[2]. House 2 had an *unfurnished lot value* of §15508 and a *furnished lot value* as §17491. This indicates that, in comparison to House 2, House 1 was larger in size and was equipped with a larger number of and more expensive furniture and appliances. More details regarding the structure and contents of their two houses will be presented next.

4.1.1.1 M&C House 1 – less budget constraints

Marios and Christina chose to build their house in an empty lot in Sunset Valley city. After going through the game's map, they chose a large – in comparison to the game's lots – (40X30) lot that was placed near the lake. They started creating foundations without explicitly sharing a plan regarding the size or structure of their house. In fact, they added foundations and then decided to enlarge them or delete

[2] The final budget is the remaining amount that is automatically calculated by the game, after subtracting the expenses made by the family. One would expect that the Final Budget is the outcome of the Initial Budget amount minus *furnished lot value* amount. This is not always the case in *The Sims* series because players 'lose' money when they delete items that are in the Building mode menu, as they do not get a full refund. For example, a wall is worth §70 but when is deleted by players, they get §56 as a refund.

them. Overall, M&C's house was a quite big house in comparison to the existing Sims houses. As they were building the foundations, Christina stated that she wanted their house to have an uncommon (unique) shape (C: "*it's better to be uncommon*", H1 – M1[3]) but when they deleted parts of the foundations, Marios wanted to refine them so as to get a rectangular shape. As a result House 1 changed several shapes before ending up in the one shown in Figure 4-1 below.

Figure 4-1: M&C House 1 foundations (initial)

As can be seen in Figure 4-1, when Marios and Christina were creating the walls around the house, they consciously stopped and left some parts without walls in order to place the doors and glass-doors (C: *"leave that. We will add the glass-doors there"*, H1 – M1). This was something that Stella and Katerina (Case study 4) group did while creating their first house as well. Nonetheless, in the way the game's mechanics work, a door cannot be placed if it is not supported by a wall. Thus, when they later on tried to add the doors they got a pop-up message from the game (game restriction), notifying them of this 'rule' which resulted in adding walls in the missing parts.

The ground floor of House 1 included a kitchen, a living room and a bathroom. In addition, the lot also included a swimming pool, a fountain and some trees

[3] H1-M1 is short for House 1 – Meeting 1

(Figure 4-2). The upper floor of House 1 had M&C’s separate bedrooms, another bathroom and an area of Marios’ bedroom which was eventually named as ‘shared playroom’. During the first meeting, M&C argued about the bedrooms’ area size and allocation; Christina had a larger area of the first floor as her bedroom and, according to Marios, “*a better view*”, whereas Marios had a smaller area (Figure 4-3 and Figure 4-4).

Figure 4-2: M&C’s House 1 ground floor (not final)

Figure 4-3: Christina’s bedroom (final)

Figure 4-4: Marios' bedroom (left), Christina's bedroom (right) and playroom

When Marios and Christina started furnishing House 1, there were large sized areas which seemed 'empty' and they decided to add many of the same furniture and appliances in order to 'fill in the space', i.e. by adding 4 TVs one next to each other in the bedroom or 4 toilets in one bathroom. Considering a real-life house, this was something odd. However, this was one of their 'solutions' to the 'problem' of having empty areas as a result of creating a large house. This is illustrated in more detail in Chapter 6 (see Section 6.2.1.1, p.167).

4.1.1.2 M&C House 2 – with budget constraints

The researcher demonstrated the family inventory menu and highlighted the new feature of this aspect of the game, which included a budget. Players were introduced to the Simoleons (game's currency) and were asked to choose a family from the inventory[4]. Marios and Christina chose to build a house for the Williams family (a couple with a baby) with a budget of §20125. When they tried to place the family on an empty lot, they realized that they could not, because the empty lots were not available[5]. They discussed whether to merge the Williams family with existing

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[4] This was done for all groups, in a similar manner

[5] *The Sims* 3 allows players who wish to place a Sims family from the inventory into the neighbourhood to only buy existing houses/buildings and not empty lots.

families or buy an existing house for them. But they wanted to buy an empty lot and build a house from scratch for that family. Then Marios suggested choosing an empty lot (without choosing the family) and build one square of foundation and save the game. Marios' plan worked and the lot was considered by the game as a house rather than an empty lot, and was available for purchase[6]. After doing that, they chose the family and bought the lot-house. Initially, they created a 24X20 house because they wanted to create a small house, as they said. They then added and deleted foundations until they got a desirable shape of the house (Figure 4-5). Marios did not want the family's baby to be in a separate bedroom but Christina wanted to have a separate bedroom "*for later*". As soon as they added the walls and started furnishing the rooms of the house, they realized that they did not have enough money to add a toilet in the bathroom. They decided to stop and continue building the house during their next meeting as having a bathroom was important to them and the family's needs.

Figure 4-5: M&C's House 2 (2nd meeting stage)

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6 Marios and Christina were the first group to play the game and their proposal of adding a foundation square in the empty lot so as to be considered as a house was what the researcher suggested later on to other groups to do. In fact, this was the only way to get a family from the inventory to buy an empty lot!

During the next meeting, Marios and Christina decided to reduce the size of the house by deleting the parents' and the baby's bedrooms in order to increase the family's budget balance. They then created a bedroom next to the kitchen area and placed trees in order to decorate the area (Figure 4-6). Eventually, Marios and Christina ended their gameplay of House 2 with a budget balance of §9, despite the fact that they wanted to leave the family with more money. This was because they needed to refine their house, by adding wallpapers and making sure that there were not unfinished rooms, so as to make their Sims happier. This was something that was indicated by the game's Sims mood and need meters that appeared when they played with the Live mode gameplay. This will be furtherly discussed in Chapter 6 (see Section 6.2.4.1, p.190).

Figure 4-6: M&C's House 2 (almost final)

4.2 Case study 2: Alexia and Eleni

Alexia and Eleni (A&E) are two 12 year-old girls (Year 6) living in a suburban area of Nicosia. They have been friends for six years and they go to the same school. They live close to each other and their parents are friends. While playing the game, the girls mentioned that they enjoyed art and music and that they wanted to become fashion designers in the future. During their gameplay they wanted their house to look nice so they spent a lot of time decorating and changing the colours of their houses. When their gameplay was constrained by the family's budget (House 2), the girls seemed disappointed with the cheap choices they were making, in terms of the appearance of the house and furniture but once they remembered the 'Create a Style' option of the game that they had discovered during the House 1 gameplay they seemed happier. They used this option a lot in order to decorate the 2nd house, the way they wanted without having to choose more expensive items that "looked better". During House 2 gameplay the girls mentioned that they were aware of keyboard cheats, related to the budget's balance similarly to Marios and Christina. They had not played *The Sims 3* series before but they admitted that they had talked about it with friends at school and that they had done an online search about the game.

A general comment on Alexia and Eleni's interaction during gameplay is that they mostly agreed before proceeding with their actions for building both virtual houses but it appears that Alexia was the one that initiated their next moves most frequently. Eleni was the one mostly agreeing and asking what their next moves would be. However, they both had their input on building, furnishing and decorating the two virtual houses.

4.2.1 Description of A&E's Houses

A&E built the two houses in a total of 3 hours and 46 minutes of gameplay, in 2 meetings. As shown in Table 4-2, they spent 2 hours and 10 minutes of their total gameplay to build House 1 (less budget constraints) and 1 hour and 36 minutes to build the House 2 (for a family, with budget constraints). The girls created and furnished House 1 during the first meeting and then proceeded with building and furnishing House 2 during the 2^{nd} meeting.

	Gameplay time (h)	Furnished lot value	Unfurnished lot value	Initial budget	Final budget
House 1	2:10	67758	§46759	-	-
House 2	1:36	§12281	§10671	§20000	§6459

Table 4-2: A&E overview of Houses 1 and 2

The final *unfurnished lot value* of House 1 was §46759, whereas the *furnished lot value* was §67758 (Table 4-1). This means that A&E created a house that was more balanced in terms of the furniture and appliances' value and the building structure value in comparison, for example, to Marios and Christina's House 1. For House 2, A&E selected a family with a total budget of §20000 available to spend for buying a lot and building a house. When they finished House 2, the family's budget balance was §6459. House 2 had an *unfurnished lot value* of §10671 and a *furnished lot value* as §12281. This indicates that, in comparison to House 1, House 2 was smaller in size and was equipped with a smaller number of and cheaper furniture and appliances. More details regarding the structure and contents of their two houses will be presented next.

4.2.1.1 A&E House 1 – less budget constraints

Alexia and Eleni chose to build their house in Sunset Valley city. They chose a 20X30 lot from the map that was placed near the lake. They created a single floor house the size of which was influenced by the neighbour house's size (Figure 4-7). While building the foundations, the girls zoomed out the camera and noticed the neighbour's house and they decided to create a similar sized house. Alexia said: *"Oh, look at the neighbour's house, I think we need to expand our house"* (A&E, H1 – M1) and Eleni agreed.

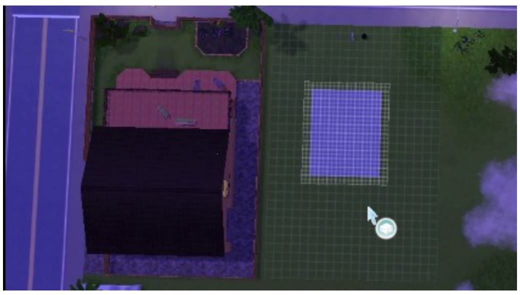

Figure 4-7: A&E comparing their foundations to the neighbour's house

Their first house had a kitchen, a living room, a bathroom, a bedroom, a playroom and a dining room. The girls created hallways in a cross shape in order to make their rooms accessible. They first created rectangular shaped foundations which they separated in 4 rooms. Unlike the other 3 groups, the girls followed a different pathway of building their house; they proceeded with furnishing and decorating each room before moving on to the next one. When they created all four rooms they then decided that they needed a kitchen and a living room which they built as an extension of the other four rooms (see Figure **4-8**). Perhaps A&E's building sequence of first furnishing each room before building the next room was one of the reasons why those girls managed to build a small house – in comparison to the other Sims' houses – in House 1 gameplay.

It is worth mentioning that, initially, they wanted to turn a room of the house into a fashion studio but because they could not find sliding doors and other accessories that they needed for that room, they abandoned the idea and they used that room for a baby's playroom afterwards. In fact, when they were talking about this house, they referred to a third person *"The woman will have her bedroom here"* (H1 – M1) which indicates that they perhaps considered that the house they were creating was for someone else, i.e. a Sims character.

Figure 4-8: Alexia and Eleni's House 1 – Outdoors (final)

The girls decided to create a swimming pool around the house except from an area of grass near the pavement so as to create the house's entrance. However, since they had already created each room, they had difficulties with the accessibility of the house, as the front entrance of the house was actually leading to the house's bathroom/toilet. They faced difficulties creating entry points for their house and they spent some time figuring out ways on getting entry points without deleting the swimming pool. Even though they wanted the swimming pool to be a unified one, they eventually had to split the swimming pool in three parts in order to create foundations (as pathways) and make entry points for the hallways and the living room as shown in Figure 4-8 and Figure 4-9.

Figure 4-9: Alexia and Eleni's House 1 – indoors (final)

4.2.1.2 A&E House 2 – with budget constraints

The girls chose an empty lot for the Glover's family (a man and a woman – roommates) that had a §20000 budget. They created a single floor house with a shared bedroom with two beds, a kitchen, a living room with a dining table and a bathroom. They were aware that the two Sims were not a couple (roommates) but, as they said, *"It's a big room, they can share it"* and they created a bedroom with two single beds. As they were building their house Alexia said: *"A bedroom, a bathroom, a living room…now we do the kitchen, what else is necessary? Is there anything else necessary?"* (H2 – M2) indicating that their plan might have been to build what was *'necessary'*. They chose the cheapest available furniture for this house and they chose the free tiles and wallpapers to decorate the house. The girls, similarly to their House 1 gameplay, placed the entrance of the house in a non-expected place, away from the street. They used stones to create a decorative boarder of the house as they wanted to make a pathway for their Sims to reach the entrance door (Figure 4-10).

Figure 4-10: Eleni and Alexia's 2nd house (final)

The girls were not satisfied with the decoration of this house (tiles and wallpapers mostly) because they chose to use the free options for wallpapers and tile's designs because the ones they liked and had used in their first house were more expensive. However, towards the end of their 2nd meeting gameplay, Eleni remembered the 'Create a Style' option which they had first used in House 1. The 'Create a Style' option (See Figure 4-11) is a feature of the game that allows players to customize the colour, texture and overall appearance of existing wallpapers, tiles, furniture colours and so on without increasing the value (price). The girls added free wallpapers to decorate the outside walls of the house and then used the 'Create a Style' option so as to change the appearance of the outside walls of the house for free. They left the family with a budget of §6459 when they finished the house because as Alexia said: *"They are unemployed"* (H2 – M2). The girls did not face particular difficulties with this house as far as the budget is concerned. After finishing their 2nd house, the girls played with their Sims and added stairs for *The Sims* to be able to enter the house.

Figure 4-11: Sims' 'Create a Style' option (A&E, House 2)

4.3 Case study 3: George and Nikos

George and Nikos (G&N) are the youngest group of participants in this research. They are 8 and a half years old (early Year 3) and they live in an urban area in Nicosia. They are classmates and good friends and, as they said, they meet after school and play regularly. They had never played *The Sims 3* game before but Nikos mentioned that his older brother played something similar. George and Nikos met twice in order to build the two houses in George's house and there were a few minutes during their House 2 gameplay where George's younger brother was present because as he said he wanted to see what they were doing. During their gameplay and as they were selecting cars for their first house, George mentioned that he would like to create a car repair garage in the game, because he wants to become a car mechanic in real life. It is worth mentioning that the boys faced some difficulties navigating in the game's menu and also using the keyboard shortcuts during their first meeting and the researcher was providing tips in respect to the game's controls. After one hour of gameplay, however, they could handle the mouse and keyboard quite successfully on their own.

A general comment on their collaboration is that George appeared to share his thoughts with Nikos more than Nikos did. George usually justified his suggestions and requests whereas whenever Nikos controlled the mouse, he tended to add/subtract items without justifying his choice. He did, however, wait until George agreed. What was noticeable was that during the building of the 2nd house (with budget constraints), George was more active in comparison to Nikos and expressed more often his 'frustration' when they were running out of money. Particularly, Nikos was sometimes distracted either by George' younger brother who was around for a few minutes or by eating snacks. Hence, he was not looking at the computer screen all the time. By the end of the 2nd meeting, George asked the researcher whether she could provide them with the game to continue playing. Lastly, when they were finishing their 2nd house in House 2 gameplay, George said that he enjoyed creating both houses whereas Nikos said he enjoyed creating the first house because they could add as many cars as they wanted and many items were free.

4.3.1 Description of G&N's Houses

George and Nikos built the two houses in a total of 3 hours and 1 minute of gameplay, in 2 meetings. As shown in Table 4-3, they spent 1 hour and 59 minutes of their total gameplay to build House 1 (less budget constraints) and 1 hour and 2 minutes to build House 2 (for a family, with budget constraints). In order to finish the first house, the boys had to work on it for the first 15 minutes of the 2nd meeting. Furthermore, when they were done with their 2nd house, they returned to the first house in order to add 4 cars.

	Gameplay time (h)	Furnished lot value	Unfurnished lot value	Initial budget	Final budget
House 1	1:59	§91802 (§321002[7])	§80670	-	-
House 2	1:02	§17732	§16602	§20000	§222

Table 4-3: G&N overview of Houses 1 and 2

The final *unfurnished lot value* of House 1 was §80670, whereas the *furnished lot value* was §91802 (Table 4-3)**.** When the boys added the expensive cars to their first house in the end of their 2nd meeting, the *furnished lot value* got §321002. This was because they selected four cars which they cost a total of §229200. Stella and Katerina group (Case study 4) was the only other group which added cars in their house, increasing the total *furnished lot value*. Although the game considers cars as part of the *furnished lot value*, for the purposes of this research and in order to be able to analyse and compare the cost and size of their house, the value of the cars will not be calculated in the total *furnished lot value*. Thus, for G&N's gameplay, the total *furnished lot value* of their first house was considered as §91802.

For House 2, George and Nikos selected a family with a total budget balance of §20000. When they finished House 2, the family's final budget balance was §222. House 2 had an *unfurnished lot value* of §16602 and a *furnished lot value* of §17732.

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[7] The total value of the furnished lot of G&N's first house was §92.010. However because the boys added cars to their house the indicated by the game total of the *furnished lot value* was §321.002.

This indicates that, in comparison to House 1, House 2 was smaller in size and was equipped with a smaller number of and cheaper furniture and appliances. The boys did not manage to finish House 2 without spending the entire family's budget balance and therefore, similarly to Marios and Christina, they had to think of ways to increase the family's budget. More details regarding the structure and contents of their two houses will be presented next.

4.3.1.1 G&N House 1 – less budget constraints

George and Nikos chose an empty lot in the Sunset Valley city. The lot was facing the lake because as George stated *"there is a view"* (H1 – M1). House 1 was a three-level house in which the ground floor had two toilet rooms, a bathroom, a kitchen and a living room (Figure 4-13), the first floor had an extra kitchen room and two bedrooms which were connected with two bathrooms (Figure 4-16 and Figure 4-17) and the third floor was left empty apart from the staircase they had added to connect all floors of the house all the way up to the roof. They created two swimming pools on the roof (Figure 4-14) which, as an idea, started when they noticed that the roof could be flat, while they were creating the first floor of the house.

Figure 4-12: G&N – Ground floor structure (House 1)

There was not seem to be a plan when they started creating the ground floor rooms but they both agreed to create a kitchen, a living room and toilets. They created the rooms of the ground floor without placing any furniture in it and they then placed doors, windows and lights for all ground floor rooms as shown in Figure 4-12 above and moved on to create the upper floor.

It is worth mentioning that they added windows on the internal walls of the house and when they were asked by the researcher why, they said that they wanted to be able to see what was going on in the house (Figure 4-13). They also changed the shape and allocation of the rooms in House 1's ground floor as they were proceeding with their gameplay. For example, the kitchen area was initially two rooms which were merged into one.

Figure 4-13: G&N – Ground floor (House 1) finished

The boys did not seem to have a plan regarding the size of the bedrooms of the upper floor either. They created a bedroom on the one side of the house which was attached to a bathroom and then another bedroom on the opposite side of the house, attached to a bathroom as well. Seeing that there was a large empty area between the bedrooms in the upper floor, Nikos suggested creating an extra room on the first floor which they could use as their kitchen but he did not explain why there was a need for a second kitchen in the house (Figure 4-17). It is worth mentioning that before furnishing the upper floor's rooms, George and Nikos created a 2nd floor which led to the roof with the two swimming pools (Figure 4-14).

Figure 4-14: G&N – Roof (House 1)

They then returned to the ground floor to place furniture. The size of the ground floor (and therefore the other floors of the house) was relatively large in comparison to the other Sims houses. Thus, when they started furnishing the ground floor's rooms, there was a lot of "empty" space that they had to think of what to do with, similarly to Marios and Christina. They placed two bathtubs in one of the bathrooms and they also placed 16 benches in the kitchen. It seemed that they wanted to *"fill in the empty space"* (H1 – M1), as George said with more items (Figure 4-15).

Figure 4-15: G&N – Ground floor kitchen's benches (House 1)

When the boys were done with the ground floor, they furnished the upper floor's rooms. The boys referred to the bedrooms and bathrooms of the upper floor as their own and they furnished their bedrooms and bathrooms individually. However, they were talking, setting questions or providing advice when each one was furnishing his room at that time. For example, Nikos added a shower and toilet in his bedroom and George asked him why, because as he said, he had already created a bathroom just next door. Nikos replied that he wanted a shower in the bedroom *"for a fast shower"* (H1 – M1).

Figure 4-16: Nikos' bedroom and bathroom

Figure 4-17: George bedroom and bathroom and first floor kitchen

4.3.1.2 G&N House 2 – with budget constraints

George and Nikos went through all available families in the family inventory, so as to choose the family to build House 2 for. Nikos stated that a couple (man and woman) is not a family and he wanted to discard all couples from their choices. However, after viewing all available families, Nikos suggested choosing a family with a high budget balance. The researcher also pointed out the "difficulty" level that the game had for each family and explained that the more members a family had the more difficult it was for players to control each member's life in the Live mode gameplay. Even though Nikos initially discarded the couples, he eventually agreed to choose the Glover family (a man and a woman who were roommates) with a budget of §20000 (the second highest budget) which was suggested by George. As they explained, they chose the specific family because they had enough money, were young and not difficult to play.

The boys started looking for a lot to build the house for the Glovers and George suggested getting a certain lot that was near the sea. The researcher mentioned that the specific lot was worth §6800 and the family had §20000 as an overall budget. Nonetheless, George and Nikos stated that they could manage to create the house because they planned to build a small house in that "expensive" lot as it was important for them to be near the sea. They placed the foundations and walls and the budget's balance went down to §4371 (Figure 4-18). At that time Nikos asked the researcher: *"we have so little money now… what will happen if we run out of money?"* (H2 – M2). The researcher answered that furniture and other features of the building mode will start having a red colour indicating that the family cannot afford to buy them.

The boys deleted the ground floor's foundations and walls several times so as to get more money and decided to have a single floor house. Figure 4-18 shows the initial design, Figure 4-19 the second stage where they deleted part of the south area of the house to get more money and Figure 4-20 shows the final structure of their house, in which they deleted parts of the house, to get more money.

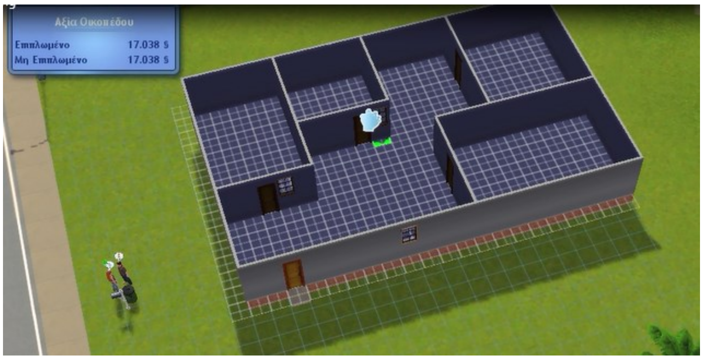

Figure 4-18: G&N – House 2 (initial shape)

Figure 4-19: G&N – House 2 (2nd stage)

Figure 4-20: G&N – House 2 (final structure)

G&N eventually created four rooms; a bedroom, a kitchen, a bathroom and a living room for the family. All rooms had one door, one lamp and one window. The boys added tiles in all rooms but they did not use any wallpapers to decorate their house. As shown in Figure 4-20, the bedroom was furnished with 1 double bed only, the bathroom with a sink, a toilet and a shower, the living room had a TV, a couch, a Hi-Fi system and a table with two chairs and lastly the kitchen was equipped with a table with two chairs, a fridge, an oven, a dishwasher. The boys played with their Sims when they had finished House 2 and made some adjustments to their house, such as adding stairs in the front entrance so as to get their Sims in the house. In addition, the boys added a Hi-Fi system so as to increase their Sims' mood meter as they noticed that their entertainment meter indicator was low. It is worth mentioning that their Sims' overall mood meter was lower because, similarly to the other groups, they had left parts of the house unfinished, but the boys did not see that. For example, as it is shown in Figure 4-20, none of the rooms had wallpapers.

4.4 Case study 4: Stella and Katerina

Stella and Katerina (S&K) are 9 and a half years old and they both live in an urban area in Nicosia. They are both in the same classroom (early Year 4) and they have been friends for three years. They meet and play regularly, because they live close to each other and their parents are friends. None of them has played *The Sims* series before. A general comment on their collaboration is that Katerina seemed more comfortable controlling the mouse. Nonetheless, she asked for Stella's opinion before proceeding. During that time, the girls discussed their actions beforehand and Stella was the one using expressions like "place that there" whereas Katerina was using expressions like "shall we place that there?". During their gameplay they appeared to work together smoothly and did not have incidences of tension between them apart for a time when Katerina wanted the family of House 2 to have a dining room and Stella did not.

Overall, they both agreed on most of their activity. They were both happy with their houses' appearance, even though they were not initially happy with House 2 appearance and furniture. Similarly to A&E, the girls spent a lot of time deciding on painting decorations and colours of tiles, wallpapers and furniture for their house as the appearance of the house seem to be very important for them. Stella mentioned during their gameplay that she was going to Art classes and she liked the paintings that the menu of the game had. S&K discovered the ‘Create a Style’ option and also the ‘Eyedropper’ option which they used in order to decorate House 2 whilst saving on the budget.

4.4.1 S&K Houses – Description of Artefacts

Stella and Katerina built the two houses in a total of 4 hours and 57 minutes of gameplay, in 2 meetings. As shown in Table 4-4, they spent 3 hours and 42 minutes of their total gameplay to build House 1 (less budget constraints) and 1 hour and 15 minutes to build the House 2 (for a family, with budget constraints). The girls spent the entire first meeting and 2 hours of their 2nd meeting in order to finish House 1.

	Gameplay time (h)	Furnished lot value	Unfurnished lot value	Initial budget	Final budget
House 1	3:42	§134778 (§304778[8])	§77214	-	-
House 2	1:15	§15209	§13370	§20000	§4.412

Table 4-4: S&K overview of Houses 1 and 2

The final *unfurnished lot value* of House 1 was §77214, whereas the *furnished lot value* was §134778, almost two times the *unfurnished lot value* (Table 4-4). This means that the girls created a large house (for *The Sims* game) which had expensive furniture. For House 2, Stella and Katerina had to create a house for a family with a total of §20000 available budget to spend for buying a lot and building a house. When they finished House 2, the family’s budget balance was §4412. House 2 had an *unfurnished lot value* of §13370 and a *furnished lot value* as §15209. Thus, the girls created a smaller house with less in number and value furniture for the family in comparison to their first house. More details regarding the structure and contents of their two houses will be presented next.

[8] The total value of the furnished lot of S&K’s first house was §134778. However because the girls added 2 cars to their house the indicated by the game total of the *furnished lot value* was §304778.

4.4.1.1 S&K House 1 – less budget constraints

S&K chose an empty lot in the Sunset Valley city. The lot was near the lake. Their first house was a three-level house in which the ground floor had a kitchen and a living room (Figure 4-21). The first floor of their house included bedrooms, offices, a bathroom and a gym. Initially, however, they placed their bedrooms and desks in the first floor but they did not separate the rooms with walls. Rather, they used a wall as a decorating item between the beds (Figure 4-22) and their desks and gym items were combined. This wall was dashed as the girls created a wall with a pattern: wall – empty space – wall. This 'dashed' wall pattern was something that they used in most of the rooms of the house, except from the bathrooms and kitchen. However, when the girls tried to place the staircase to connect the floors of the house in their 2nd meeting they had to restructure the entire first floor.

It is worth commenting that the girls did not use doors in their house apart from the front entrance door and the ground floor's guest bathroom. Rather, they used the dashed wall to separate the rooms and they deleted a wall in the kitchen and bathrooms in order to create entry points. The second floor was left empty but they put a staircase connecting all floors of the house all the way up to the roof. S&K created a rectangular shape of foundations. After creating the foundations they placed tiles and on top of the tiles a carpet. They then created the upper floors' tiles and carpets. When they were done, they created walls around the floors.

Figure 4-21: S&K – House 1 ground floor (initial)

Figure 4-22: S&K – House 1 first floor (initial)

During the 2nd meeting, the girls continued editing their first house and they added a dining room and an entertainment area in the ground floor and had to change the structure of the first floor because they faced difficulties when adding the stairs connecting the ground floor with the first floor (there were items obstructing the placement of the stairs). In addition, they wanted to place a bathroom on first floor and did not have space to do so. The final structure of the ground floor of the first house is shown in Figure 4-23 and of the first floor in Figure 4-24. As can be seen in Figure 4-24 the girls kept the dashed wall but they moved their beds on the same side of the wall and created a dashed-wall room for their desks. The girls added a swimming pool and two cars so as to finish their first house.

Figure 4-23: S&K – House 1 ground floor (final)

Figure 4-24: S&K – House 1 first floor (final)

4.4.1.2 S&K House 2 – with budget constraints

The girls chose a §1200 lot and they chose the Glover family with §20000 budget (a man and a woman) from the family inventory, that G&N and A&E also chose. They read the family's description in the inventory and were intrigued when they read: *"Will they stay just good friends or will they be something more?"* (H2 – M2). They decided to create a small ground floor house for them and were very clear from the beginning on the number of rooms they would create and where they would place them. They created a kitchen in a similar structure as their first house (they did not add a door, but deleted part of the wall to create an entry point and save money), two bedrooms, a living room area and one bathroom (Figure 4-25). They also created two separate bedrooms because they considered that their Sims were not a couple, yet. They decided to add doors in the bedrooms and the bathroom to have privacy.

Figure 4-25: S&K – House 2 before being decorated

During their gameplay and when they started spending *The Sims*' budget, Stella and Katerina seemed quite emotional and started "shouting" to the family with phrases such as *"Well, you should go get a job to get money! You are lazy"* (Stella, H2 – M2) or *"No, you don't deserve a better TV"* (Stella, H2 – M2), that were mostly stated by Stella. Stella appeared eager to finish the house using *"cheap and stupid"* (H2 – M2) items as she said, because the "nice-looking" items they used for their first house were now expensive. There was an incidence where Stella said that they had finish with that house and Katerina insisted adding a dining room but Stella did not want that. Stella wanted to get over with it because she did not like the house's appearance as she said. Katerina insisted and she justified her proposal by saying: *"Look, we have money to do that and they need to have a place for their guests to sit!"* (they had almost §6000), but Stella disagreed. Then Katerina insisted saying: *"I don't care, I will do it… It's a shame for their guests"* (H2 – M2) and she created the dining room (Figure 4-26). This was their only disagreement in their gameplay but Stella eventually agreed to add a dining table.

It is worth mentioning that once they had their Sims in the house (Live mode) they saw that they were not happy because there were unfinished rooms (which did not have wallpapers). They paused the game and they decorated all rooms to make sure that their Sims were happy. Katerina accidentally discovered the 'Create a Style' option of *The Sims*' menu, in which they could edit the colours of their creations for free, similarly to Alexia and Eleni. As soon as they realized that they could edit the appearance of the items, Stella said *"Aha! We will continue now! Let's make it pretty"* (H2 – M2). They changed the colour of their tiles using the 'Crete a Style' option but they could not do the same with the walls of the house because they had not placed wallpapers and the specific option did not allow editing walls without wallpapers. They eventually bought the house's wallpapers. Later on, the girls discovered and used the 'Eyedropper' option of the game which allows players to copy a certain style and paste it. Thus, they managed to create desired chess-like patterns of colours on the tiles, shown in Figure 4-26. The girls were happy with their choices and the appearance of the house by the end of House 2 gameplay.

Figure 4-26: Stella and Katerina's 2nd house (final).

4.5 Summary of the four groups' gameplay

In *The Sims 3* game, players can choose to play: i. the Live mode of the game and manipulate the lives and actions of existing Sims characters that live in the virtual households, ii. the Build mode of the game and build from scratch new or edit existing virtual houses and iii. the Buy mode of the game and buy furniture and other items for their Sims characters and virtual houses. As presented in this chapter, in the way this research was designed, all modes were played by the players but the Build and Buy modes were mostly played during participants' gameplay. Nonetheless, all four groups at some point towards the end of their House 2 gameplay, played with their selected Sims family in the Live mode. When the four groups chose to play the Build and Buy Modes, both in House 1 and House 2 gameplay, it was in order to build, furnish and decorate from scratch their virtual houses' in the game's environment. To do so, they had to first choose an empty plot from a virtual city map. This 3D virtual map resembles a real-life neighbourhood, in the sense that it simulates the geographical way (location, navigation, scaling etc.) that houses, plots, industrial buildings, community buildings, roads, green areas and parks are located on a real-life map. When players click on any virtual item in *The Sims 3*, they get feedback from the game displaying information regarding that particular digital item. For example, when players click on an empty plot they get information such as the name of the lot and the size (i.e. 30X40).

After selecting the empty plot, the four groups' activity of constructing a house in that plot, involved players going through a cycle of actions that are mainly related to: i. constructing the foundations of the house, ii. creating walls in order to shape the exterior and interior structure of the house by shaping the rooms, iii. decorating the walls and floors of the house by choosing wallpapers and floor designs and iv. choosing and placing furniture and other items in the house. In the groups' gameplay, those four cycles were not necessarily observed in that order, although the groups did start with building the foundations of the house as they did create the overall area of the house before proceeding with the decorations and furnishing.

Considering the process of creating a house in real-life settings, those four cycle of actions that were observed during players' gameplay in this research are processes that are followed by practitioners such as architects, constructors and civil engineers (i and ii) and interior designers and decorators (iii and iv). Of course, I do not claim that the processes followed by real-life practitioners are the same as the virtual cycles of actions that players made in order to build their virtual houses. These real-life processes require specific and sophisticated practice-linked knowledge and skills which *The Sims* players and, certainly, the young children who played this game in this research, lack.

Following different pathways of gameplay, the four groups managed to build two houses; House 1 with less budget constraints and House 2 for a family with a budget constraint. Even though they eventually created different artefacts in the game, there were some similar aspects of their gameplay. It appears that all groups created a higher total value house in House 1 gameplay in comparison to the house in House 2 gameplay. M&C, S&K and G&N created a large house in comparison to the other Sims houses of the game whereas A&E was the only group who created a single floor house in House 1 gameplay. All groups chose some expensive items from the game's menu in order to furnish and decorate their House 1. Nonetheless, all groups managed to include in House 1 at least one: kitchen, living room, dining room (or table), bathroom and bedroom. The groups who experienced difficulties with the size of the house (M&C and G&N) had many furniture items of the same kind to equip the large areas of those rooms. This exaggeration in respect to the number and type of furniture some groups bought for their House 1 in order to fill in the space instead of decreasing the size of their house might indicate that in less budget constraints players' imagination was enabled and stimulated during gameplay.

In addition, M&C and G&N created separate bedrooms on the first floor of their House 1 which they built individually. S&K on the other hand created joint bedrooms and shared items on the first floor of their House 1 which they built collaboratively the same way they were creating the rest of the house. A&E was the only group who, whilst initially aimed to create a fashion studio for themselves, they eventually built a house for a fictional woman and did not build the house for themselves. Perhaps this was because they could not find desirable furniture and other menu items that they considered necessary to use in order to create a fashion studio. Thus, the girls' initial goal was abandoned because what they needed to accomplish it was unavailable (Gresalfi et al., 2008).

When creating House 2, the groups needed to consider the family's budget. Even though all groups chose cheaper (and often the cheapest available) items from the menu in order to furnish their House 2, G&N and M&C eventually spent the entire budget of the family in House 2 gameplay before completing the house. Perhaps this was because M&C created a large house even though they initially stated that they would create a smaller house and G&N chose an expensive and large lot to build the house in. In *The Sims* game, the building items (walls, foundations etc.) cost a lot. Therefore, the two groups had to delete parts of the house in order to increase the budget and be able to continue building. Nonetheless, due to the game's mechanics they did not get a full refund and thus they were also losing money if they were extensively deleting building items. A&E and S&K on the other hand did not experience difficulties with the budget as they managed to finish their House 2 with more than a fifth of the initial family's budget remaining. The girls created a small house for the family and both of these groups appeared to have a clear idea of the house's structure and furniture.

In addition, another similarity of A&E and S&K groups was the fact that they wanted their houses to look good and they particularly spent time in House 1 gameplay to make changes to the appearance of their house into something they liked. In House 2 gameplay on the other hand and with the budget constraint they had, the girls – like the other groups – chose the cheapest available items which did not satisfy their desires in terms of their appearance. Thus, both groups explored most of the menu options and as a result, they discovered the ‘Create a style’ option which they used to change the appearance of the house and furniture in a cost-effective way. In addition, S&K group discovered the ‘Eyedropper’ option which they used in order to create patterns in the floor’s appearance. It is worth stating that M&C also wanted their House 2 to look good but they had to use the cheap (and free) items as they had not discover these options in the game’s menu.

Lastly, all groups played with their chosen family in the Live mode when they stated that they had finished the building of their house. Nonetheless, all groups, needed to pause the game and make adjustments to their house in order to create stairs so as to get their Sims in the house or add wallpapers and entertainment items so as to increase their Sims mood meter which is an integrated part of *The Sims* Live mode gameplay (See Chapter 6, Section 6.2.4, p.190).

Chapter 5 that follows will provide a more detailed description on the way the four groups’ gameplay unfolded and the way each group collaborated in order to create the two houses, by illustrating the results from the first four stages of analysis.

Chapter 5 – Gameplay, goals, actions and talk

This chapter presents the results that emerged during the first four stages of analysis of each pair's gameplay. The chapter that follows will present the results that emerged during the fifth and sixth stages of analysis. The aim of this chapter is to provide the reader with an overview of the four groups' gameplay, goals, actions and talk presented the same way I analysed the research data in the first four stages of analysis (See Section 3.5.2, p.71). Given that the same process of analysis was implemented for all four cases, the results are presented in a way that allows comparisons between the cases, for every one of the four stages of analysis. This chapter is divided in four major sections. The first section describes the categories of the open codes characterizing players' gameplay (first stage of analysis). Then, the second section, presents the way players' gameplay unfolded by illustrating the complexity of players' goals and actions (second stage of analysis). Next, the third section focuses on the way those goals were initiated and processed during each groups' gameplay (third stage of analysis) and also presents elements of the players' interaction with each other and results related to their type of talk (fourth stage of analysis). Lastly the fourth section summarizes the results presented in this chapter and brings them together so as to link Chapter 6 that follows.

5.1 Overview of gameplay – first stage: open codes and categories

This section presents results that derived from the first stage of analysis: Open Codes and Categories (see Section 3.5.2.1, p. 71). Overall, 24 open codes occurred which were then categorized into nine categories. The categories were shaped as a result of grouping the open codes that were relevant and referred to a similar concept. This section is structured as follows: First, the categories and a description of each code are presented in Table 5-1 below. Next, the frequencies of occurrence of each open code for each group are presented in Table 5-2 and lastly, the frequencies of occurrence of each category for each group are presented in Table 5-3. The latter two tables aim to provide a basic descriptive statistics overview of the results of the first stage of analysis in order to illustrate the patterns that emerged.

5.1.1 Open codes and categories – Description

Table 5-1 below presents those 9 categories and 24 open codes and also provides a brief description of each open code. A more detailed description of each open code is provided in Appendix D: Extracts from open codes and categories (p.290) in which respective extracts of actions of players' gameplay and talk are given as examples for each open code.

Categories and Open Codes	
Category 1 – Experiencing the reality of the game	
1.1 Considerations about the virtual characters in *The Sims* (i.e. Sims family)	Players explicitly consider Sims characters' needs, ambitions and reality whilst playing the game.
1.2 Accessibility and usability of the house	Players explicitly state that they are making the house they are building accessible and usable for their Sims (or any other person that might use this virtual house).
1.3 Reference to real-life houses' structure and appearance (culture and everyday experience)	Players explicitly refer to real-life houses' structure (i.e. their own house), everyday experiences and/or cultural customs (i.e. dining customs) whilst constructing the virtual houses in *The Sims* game.
1.4 Consideration regarding Sims family's safety and privacy	Players explicitly consider Sims characters' safety and privacy by making relevant constructions and/or changes to the house.
Category 2 – Appearance considerations	
2.1 Colour the tiles and the walls of the house	Players make changes to the colours of the tiles and walls of the house after talking about their suggestions
2.2 "It looks nice"	Players explicitly share their satisfaction with the result of their building activity and/or choices.
2.3 "It looks ugly", "I don't like it"	Players explicitly share their dissatisfaction regarding the result of their building activity and/or choices.
2.4 Appearance in comparison to other Sims houses	Players compare their creations' appearance to the appearance of other creations they had made in the game (i.e. previous house, neighbour's house)

Category 3 – Interaction with the game's features (options)	
3.1 The walls drop down when working with the room	Players interact with the wall drop-down option of the game that is set by default. This feature can be changed by clicking the respective menu option.
3.2 Issues navigating from one floor to another	Players encounter difficulties navigating from one floor to another (before finding out the relevant option from the game's menu)
3.3 Read pop-up and menu items	Players explicitly read the game's pop-up messages and menu descriptions
3.4 Errors and feedback / game's restrictions	The game indicates gameplay errors and restrictions (i.e. items that exceed the family's budget are marked with red colour and cannot be chosen) which affect their next steps.
3.5 Using night mode and/or grid option to view the grid	Players use the night mode or grid option to be able to view the area they are working on in a grid
Category 4 – Comparison – Area (space) – Size – Arrangement issues	
4.1 Making comparisons (size and/or value)	Players explicitly compare their own (or the game's) artefacts' size and/or value with other artefacts
4.2 Area (space) issues	Players explicitly discuss issues regarding the area (space) of their artefacts, other than comparisons
4.3 Arrangement of items and furniture	Players explicitly discuss issues regarding the position/placement of their artefacts (i.e. furniture)
4.4 House structure issues	Players explicitly discuss issues regarding the structure of their house (i.e. room positions, door's placement, hallways etc.).
Category 5 – Ways to save money / spend less	
5. Ways to save money / spend less	Players explicitly talk about ways to save money (spend less money) while building the houses. Players make cost-effective choices in order to save money.
Category 6 – View rotation and/or zoom	
6. View rotation and/or zoom	Players explicitly suggest rotating the view of the game and/or zoom in/out during their gameplay in order to get an overview of the house's appearance or to get a better angle in viewing a specific area.

Category 7 – Emotions when referring to budget issues	
7. Emotions when referring to budget issues	Players talk about budget issues in a distressed and sometimes "angry" manner. Players might argue, raise their voice and use relevant expressions. Players might also sound relieved once they manage to increase the budget's amount
Category 8 – Players' interaction with each other	
8.1 Disagreements between players regarding their choices	Players disagree regarding the progress of their gameplay and demonstrate scenes of arguments. Players try to proceed with their own individual suggestions without explaining their choice to one another.
8.2 Explanation of choices / suggestions	Players share suggestions regarding the next steps of their gameplay and explain their suggestions to each other before reaching a decision.
Category 9 – Players' interaction with the researcher	
9.1. Questions towards the researcher	Players explicitly ask for the researcher's (AA) assistance when they do not know how to proceed and/or they have a question
9.2. Tips and clues from the researcher	The researcher (AA) provides players with a tip/clue regarding the game's menu/features after they repeatedly experience difficulties related to that feature and struggle through their gameplay

Table 5-1: first stage of analysis – Open codes and categories – Description

As can be seen in Table 5-1 the categories that were shaped after merging the open codes were: *1. Experiencing the reality of the game, 2. Appearance considerations, 3. Interaction with the game's features (options), 4. Comparison-Area (space)-Size-Arrangement issues, 5. Ways to save money / spend less, 6. View rotation and/or zoom, 7. Emotions when referring to budget issues, 8. Players' interaction with each other* and *9. Players' interaction with the researcher*. Those categories illustrate two somewhat expected aspects of interaction that perhaps occur in any, collaborative gameplay: i. interaction with the game's content and features (features – options and camera view, rotation and zoom) and ii. interaction with each other and of course interaction with the researcher because the researcher was also present.

However, those categories also reveal some aspects that are perhaps more specific in the content of this particular game title: i. players' considerations regarding the appearance of their artefacts (houses) because they were building houses and also the wellbeing of the virtual characters that were involved as part of the reality of the game, ii. players' issues related to the structure, the size, the area and arrangement of the house and the house's furniture and iii. players' awareness of the family's budget which resulted in them having to think of ways to save money or spend less and also in sharing emotions of stress and/or frustration while working with a budget constraint.

Even though the description of the open codes is useful to understand the kind of actions that occurred during players' gameplay, it is important to examine the frequencies of occurrence of those open codes (and subsequently those categories) as they highlight the patterns of the groups' gameplay.

5.1.2 Frequency of occurrence of the codes (first stage of analysis)

A closer examination of the codes and categories that were produced during the first stage of analysis revealed characteristics of each groups' gameplay. Table 5-2 below presents the number of times (frequency) each code occurred for each house (House 1 – H1 and House 2 – H2) of each group's gameplay and an overall sum of each code for all groups. A percentage (rounded to the unit) of the frequency in respect to the total of the codes for each house of each group is provided in brackets next to the frequency number. For each group and each house the three most frequently occurring codes are marked **bold** and the one that is most frequently occurring is marked <u>**bold and underlined**</u>. In addition, the last two columns present the sum of each code in all groups' gameplay.

The overall numbers of the frequencies as shown in Table 5-2, show that there were 1119 occurrences of the 24 codes during the players' gameplay in both houses (H1: 603, H2: 516). The three most frequently occurring codes during the building of House 1 (with less budget constraints) for all groups were: *1. Explanation of choices / suggestions* (n=77 ≈ 13% of H1 overall), *2. Reference to real-life houses' structure and appearance* (n=58 ≈ 10% of H1 overall) and *3. Disagreements between players regarding their choices* (n=57 ≈ 10% of H1 overall). Indeed, since the players were playing the game in groups of two, it was somewhat anticipated that players would talk in order to collaboratively proceed with their gameplay, either by disagreeing with or explaining their suggestions. Thus, it was anticipated that their interaction would also occur through the codes. In addition, it appears that during the gameplay of the first house, players referred to real-life houses, as examples, whilst creating their virtual house.

When players started building the 2^{nd} house for which they had a budget constraint, the code *Emotions when referring to budget issues*, which in House 1 gameplay was quite rarely marked (n=6 ≈ 1% of H1 overall) was the most frequently occurring code in House 2 gameplay (n=62 ≈ 12% of H2 overall). Players' disagreements decreased (Code 8.1) whereas *Explanation of choices / suggestions* code remained in high numbers of frequency, as it was the 2^{nd} most frequent code during the creation of the 2^{nd} house (n=60 ≈ 12% of H2 overall). Given the explicit and visible involvement of a Sims family for which the players were building the house, the code *Considerations about the virtual characters in The Sims* increased and was the 3^{rd} most frequent code in House 2 gameplay analysis (n=46 ≈ 9% of H2 overall).

Examining Table 5-2 more closely, it appears that the overall frequency of occurrence of code *5. Ways to save money / spend less* increased steeply during House 2 gameplay as it was only once marked (0.001% of H1 overall) in House 1 gameplay and was 25 times marked (5% of H2 overall) in House 2 gameplay. Hence, players were aware of the budget constraint and were trying to find ways of saving on the budget or spending less. This is also indicated by the fact that players were explicitly talking about the budget as indicated by the high frequency of occurrence of the *Emotions when referring to budget* category during the 2^{nd} house building. However, the frequencies of occurrence of the four groups' gameplay open codes were not at the same levels in all groups. Thus it is important to also examine the frequencies of each group separately.

Code	M & C		E & A		G & N		S & K		Totals	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
1.1 Considerations about the virtual characters in *The Sims*	3 (2*)	9 (6)	2 (2)	5 (4)	13 (9)	**15 (11)**	2 (1)	**17 (14)**	20 (3)	**46 (9)**
1.2 Accessibility and usability of the house	1 (1)	3 (2)	1 (1)	2 (2)	2 (1)	1 (1)	1 (1)	2 (2)	5 (1)	8 (2)
1.3 Reference to real-life houses' structure and appearance (culture and everyday experience)	**21 (13)**	**12 (8)**	9 (8)	6 (5)	17 (11)	10 (8)	11 (6)	3 (3)	**58 (10)**	31 (6)
1.4 Consideration regarding Sims family's safety and privacy	1 (1)	4 (3)	1 (1)	3 (3)	4 (3)	6 (5)	1 (1)	4 (3)	7 (1)	17 (3)
2.1 Colour the tiles and the walls of the house	9 (6)	7 (5)	**16 (14)**	**12 (11)**	2 (1)	3 (2)	12 (7)	3 (3)	39 (6)	25 (5)
2.2 "It looks nice"	7 (4)	3 (2)	**14 (12)**	5 (4)	3 (2)	4 (3)	**<u>28 (16)</u>**	5 (4)	52 (9)	17 (3)
2.3 "It looks ugly", "I don't like it"	8 (5)	4 (3)	5 (4)	8 (7)	0 (0)	2 (2)	8 (4)	4 (3)	21 (3)	18 (3)
2.4 Appearance in comparison to other Sims houses	2 (1)	1 (1)	2 (2)	2 (2)	0 (0)	1 (1)	0 (0)	1 (1)	4 (1)	5 (1)
3.1 The walls drop down when working with the room	3(2)	1 (1)	3 (3)	2 (2)	1 (1)	1 (1)	2 (1)	0 (0)	9 (1)	4 (1)
3.2 Issues navigating from one floor to another	4 (2)	0 (0)	2 (2)	0 (0)	1 (1)	0 (0)	1 (1)	0 (0)	8 (1)	0 (0)
3.3 Read pop-up and menu instructions	4 (2)	2 (1)	3 (3)	2 (2)	0 (0)	0 (0)	1 (1)	1 (1)	8 (1)	5 (1)
3.4 Errors and feedback / game's restrictions	**13 (8)**	15 (10)	7 (6)	3 (3)	8 (5)	2 (2)	**21 (12)**	2 (2)	49 (8)	22 (4)
3.5 Using night mode and/or grid option to	6 (4)	4 (3)	5 (4)	2 (2)	2 (1)	2 (2)	1 (1)	0 (0)	14 (2)	8 (2)

view the square grid										
4.1 Making comparisons (size and/or value)	9 (6)	12 (8)	2 (2)	**12 (11)**	2 (1)	7 (5)	4 (2)	13 (11)	17 (3)	44 (9)
4.2 Area (space) issues	4 (2)	3 (2)	2 (2)	2 (2)	7 (5)	7 (5)	11 (6)	0 (0)	24 (4)	12 (2)
4.3 Arrangement of items and furniture	3 (2)	8 (5)	1 (1)	3 (3)	11 (7)	4 (3)	16 (9)	1 (1)	31 (5)	16 (3)
4.4 House structure issues	4 (2)	7 (5)	3 (3)	1 (1)	7 (5)	6 (5)	4 (2)	2 (2)	18 (3)	16 (3)
5. Ways to save money / spend less	0 (0)	6 (4)	0 (0)	3 (3)	0 (0)	11 (8)	1 (1)	5 (4)	1 (0.001)	25 (5)
6. View rotation and/or zoom	6 (4)	3 (2)	8 (7)	5 (4)	0 (0)	0 (0)	5 (3)	0 (0)	19 (3)	8 (2)
7. Emotions when referring to budget issues	3 (2)	9 (6)	1 (1)	**14 (12)**	1 (1)	**18 (14)**	1 (1)	**21 (18)**	6 (1)	**62 (12)**
8.1 Disagreements between players regarding their choices	**27 (17)**	**16 (10)**	1 (1)	2 (2)	**25 (17)**	6 (5)	4 (2)	7 (6)	**57 (9)**	31 (6)
8.2 Explanation of choices / suggestions	12 (7)	**17 (11)**	**20 (17)**	**13 (12)**	**21 (14)**	**14 (11)**	**24 (13)**	**16 (13)**	**77 (13)**	**60 (12)**
9.1. Questions towards the researcher	5 (3)	4 (3)	3 (3)	4 (4)	3 (2)	5 (4)	6 (3)	7 (6)	17 (3)	20 (4)
9.2. Tips and clues from the researcher	6 (4)	3 (2)	4 (3)	2 (2)	**19 (13)**	6 (5)	13 (7)	5 (4)	42 (7)	16 (3)
Total	**161**	**153**	**115**	**113**	**149**	**131**	**178**	**119**	**603**	**516**

*In brackets is the percentage of each code in respect to the total number of codes for each house (i.e. Code 1.1. appeared 3 times in H1 (M&C) and the percentage 2% in brackets was calculated as follows: 3/161 *100% ≈ 2%)

Table 5-2: Frequency occurrence of gameplay codes

Starting with M&C, their interaction with each other, either to explicitly express their disagreements or explain their choices, was mostly characterizing their gameplay. They also encountered several issues with the game's rules, as there were game's errors and restrictions that were displayed by the game during their gameplay in both houses. In addition, M&C often referred to real-life houses' structure and appearance, perhaps as examples, while they were building both their virtual houses.

Furthermore, A&E mostly interacted with each other whilst explaining their choices and suggestions in both house's gameplay. Colouring the tiles and wall of both houses was also something that mostly characterized their gameplay because they wanted their house to look nice. Even though the girls did not face issues related to the family's budget, they expressed their emotions regarding the budget quite often in House 2 gameplay.

What mostly characterized G&N's gameplay was their interaction with each other by either disagreeing with or explaining their suggestions during gameplay. In addition, the boys expressed their emotions regarding the budget in House 2 gameplay as they were one of the two groups who spent the family's budget before finishing their house. Nonetheless, they seem to be the group that was mostly concerned regarding the virtual characters of the game in both houses.

Similarly to A&E, making their houses look nice was something that mostly characterized S&K's gameplay as well. The girls explained their suggestions to each other in both houses' gameplay and experienced the most game restrictions than any other group during their House 1 gameplay. When working on House 2, the girls appeared to be considering the virtual characters of the game and even though they did not experience issues with the budget they were also expressing their emotions regarding the budget.

5.1.3 Frequency of occurrence of the categories (first stage of analysis)

When codes were grouped into categories, a sum of the frequency numbers (of Table 5-2) of the corresponding codes to each category was calculated. Table 5-3 below shows the frequency that each category overall occurred during players' gameplay in both houses for each group.

Overall – Categories	M & C		E & A		G & N		S & K		Totals	
	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
1. Experiencing the reality of the game	**26 (16**)**	**28 (18)**	13 (11)	**16 (14)**	**36 (24)**	**32 (24)**	15 (8)	**26 (22)**	**90 (15)**	**102 (20)**
2. Appearance considerations	**26 (16)**	15 (10)	**37 (32)**	**27 (24)**	5 (3)	10 (8)	**48 (27)**	13 (11)	**116 (19)**	65 (13)
3. Interaction with the game's features (menu and content)	**30 (19)**	22 (14)	**20 (17)**	9 (8)	12 (8)	5 (4)	26 (15)	3 (3)	88 (15)	39 (8)
4. Comparison – Area (space) – Size – Arrangement issues	20 (12)	**30 (20)**	8 (7)	**18 (16)**	**27 (18)**	**24 (18)**	**35 (20)**	16 (13)	**90 (15)**	**88 (17)**
5. Ways to save money/spend less	0 (0)	6 (4)	0 (0)	3 (3)	0 (0)	11 (8)	1 (1)	5 (4)	1 (0.001)	25 (5)
6. View rotation and/or zoom	6 (4)	3 (2)	8 (7)	5 (4)	0 (0)	0 (0)	5 (3)	0 (0)	19 (3)	8 (2)
7. Emotions when referring to budget issues	3 (2)	9 (6)	1 (1)	14 (12)	1 (1)	18 (14)	1 (1)	**21 (18)**	6 (1)	62 (12)
8. Players' interaction with each other	**39 (24)**	**33 (22)**	**21 (18)**	15 (13)	**46 (31)**	**20 (15)**	**28 (16)**	**23 (19)**	**134 (22)**	**91 (18)**
9. Players' interaction with the researcher	11 (7)	7 (5)	7 (6)	6 (5)	22 (15)	11 (8)	19 (11)	12 (10)	59 (10)	36 (7)
Total	**161**	**153**	**115**	**113**	**149**	**131**	**178**	**119**	**603**	**516**

Table 5-3: Frequency of occurrence of gameplay categories

**In brackets is the percentage of each category in respect to the total number of categories for each house (i.e. Category 1 appeared 26 times in H1 (M&C) and the percentage 16% in brackets was calculated as follows: 26/161 *100% ≈ 16%)

Table 5-3 above provides a broader overview of players' gameplay that reveals some aspects of their actions. It appears that in total, players' gameplay during the building of both houses was mostly characterized by the following categories: *Category 8. Players interaction with each other* (n=134, 22% of H1; n=91, 18% of H2), *Category 1. Experiencing the reality of the game* (n= 90, 15% of H1; n=102, 20% of H2) and *Category 4. Comparison – Area (space) – Size – Arrangement issues* (n=90, 18% of H1; n= 88, 17% of H2). *Category 2. Appearance considerations* is frequently appearing while building the first house but its frequency decreases in the 2nd house (n=116, 19% of H1; n=65, 13% of H2).

Even though each group followed different gameplay pathways in order to build the two houses, it appears that the aforementioned categories largely characterized each group's gameplay. Category 1 is highly associated with the specific video game's content and aims since *The Sims 3* is a game that simulates real life with virtual characters, houses and options. This category also involves understandings of everyday experiences such as of i.e. the way a house is structured. Category 4 indicates an association with mathematics as the terms: comparison, area, size and arrangement are highly associated with mathematical understandings and Category 8 encapsulates players' interaction with each other. This underlying interplay of *game – everyday understandings – mathematical understandings – players* will be discussed in more detail in the Discussion chapter.

Nonetheless the results of the first stage of analysis only provided an overview of the players' gameplay. The next section will present more analytically the way the players' gameplay unfolded.

5.2 Players' major goals and sub-goals

The results of the first stage of analysis in Section 5.1 earlier provided an overview of the players' gameplay. However, it was essential to examine players' gameplay by identifying their goals and actions. As the players of all groups proceeded with their gameplay, they were setting goals that directed the actions they were performing during their gameplay. As explained earlier in Section 3.5.2.2 (p. 73), this was achieved by asking the questions *"What did they do?"* and *"Why did they do it?"* in order to identify their actions and the goals that directed those actions respectively. Many of the goals the players formed were complicatedly connected to each other in the sense that they were occurring while players were working on a previously formed goal. Thus, there was a need to distinguish between these goals and *major goals*, which were goals that were initially directing players' actions. Those complicatedly connected goals, were named as *sub-goals*: goals that were also directing players' actions, but were 'must do' things that came into being and emerged while players were working on a previously formed goal, indicating what players *needed* to do and served as "means to ends" to a *major goal*. Table 5-4 below presents the number of major goals and sub-goals that were formed in House 1 (H1) and House 2 (H2) gameplay by each group. The table also presents the number and percentage of the sub-goals that were eventually achieved, paused or abandoned by the players during their gameplay.

Major goals and sub-goals	**M & C**		**A&E**		**G&N**		**S&K**	
	H1	H2	H1	H2	H1	H2	H1	H2
Major Goals (MG)	**38**	**29**	**28**	**18**	**32**	**27**	**57**	**23**
Sub-goals (SG)	**129**	**58**	**95**	**48**	**102**	**42**	**185**	**54**
Ratio of MG / SG	0.29	0.50	0.29	0.38	0.31	0.64	0.31	0.43
SG – achieved	112 (87)	52 (90)	86 (91)	47 (98)	94 (92)	39 (93)	163 (88)	50 (93)
SG – paused	12 (9)	5 (9)	6 (6)	0 (0)	6 (6)	3 (7)	16 (9)	3 (5)
SG – abandoned	5 (4)	1 (2)	3 (3)	1 (2)	2 (2)	0 (0)	6 (3)	1 (2)

Table 5-4: Major goals and sub-goals (all groups)

*In brackets is the percentage (rounded to the unit) of each item in respect to the total number of items for each house (i.e. 112 sub-goals were achieved of a total of 129 in H1. Thus, the percentage is calculated as follows: 112/129 *100% ≈ 87%)

Examining the numbers of major goals and sub-goals as shown in Table 5-4 three observations are worthy of commenting because they show the complexity of players' gameplay and the interconnection of the goals that emerged during gameplay. First, in House 1 gameplay, the number of the sub-goals is almost triple in comparison to the number of the major goals in all groups. This observation indicates that during House 1 gameplay there were almost three times more 'things' that were 'needed to be done' in comparison to the number of the initially set major goals. This means that the goals that were initially set by the players were complex goals which required setting additional goals (sub-goals) and performing respective actions in order to be achieved.

Second, the number of sub-goals that were set in House 1 gameplay were almost double in all groups (in S&K group were in fact almost triple) in comparison to the number of sub-goals that were set in House 2 gameplay. This was somewhat expected considering that during House 1 gameplay players were familiarising themselves with the game and the game's rules (Bourgonjon et al., 2010; Gee, 2003) and also considering that all groups spent more time creating the first house in House 1 gameplay.

A third observation is the fact that even though the numbers of major goals and sub-goals decrease in House 2 gameplay (in comparison to the respective House 1 gameplay numbers), the ratio of the major goals to the sub-goals in House 2 gameplay increases in all groups. This increase of the ratio of the major goals / sub-goals might indicate that in House 2 gameplay, the groups were, perhaps, more specific and focused in terms of what they wanted to do. Furthermore, this might also mean that the players were more experienced with the game's mechanics and thus, as mentioned earlier, less things were 'needed to be done' in terms of familiarization with the game in House 2 gameplay.

Examining more closely the sub-goals and their status of achievement, most of the sub-goals that were set by the players in both House 1 and House 2 gameplay were achieved in all groups. In fact, all groups had an increased percentage of sub-goals' achievement in House 2 gameplay in comparison to House 1 gameplay and very few sub-goals were paused or abandoned in House 2 gameplay. The latter observation enhances the argument that players were more experienced and perhaps more specific in what they wanted to do.

It is worth mentioning that M&C and S&K were the groups with the most sub-goals paused and abandoned in House 1 gameplay. Those two groups had also in common the fact that they had the *"Errors and feedback / game's restrictions"* code as one of the most frequently occurring open-codes. Examining the paused and abandoned sub-goals of the groups, it appears that 4 of the 5 sub-goals that were abandoned in

House 1 gameplay of M&C and all 6 sub-goals that were abandoned in S&K House 1 gameplay involved errors and/or restrictions of the game. For example, sub-goal 100: *“Create a swimming pool in Marios’ bedroom”* was abandoned because when Marios tried to create the swimming pool on the first floor of House 1 the game displayed an error message saying *“Can’t intersect other objects”* (Figure 5-1) and did not allow them to do so. This was because the swimming pool needed to connect to the ground floor’s area because of its depth and they had already placed other items there, such as the living room’s lights right below that first floor area. They tried several ways to get the swimming pool in that area but eventually Marios said: *“No, it can’t be placed. Let’s add one outside”*. Such errors related to items intersecting each other were displayed quite often during gameplay and was something that all groups faced during their gameplay.

Figure 5-1: Sub-goal 100 (House 1) game restriction/error

Additionally, it is worth commenting that game’s restrictions also affected 7 of the 16 sub-goals that were paused during S&K gameplay. An example from S&K gameplay that is related to the game’s restrictions and shows the complexity of the emergence of the sub-goals during the gameplay, is the following example of pausing sub-goal 165 in House 1 gameplay. As described earlier (In Section 4.4.1.1, p. 113) the arrangement of the furniture and the overall room structure of the first floor of S&K first house resulted in restrictions in placing the stairs to connect the floors of the house. When they were working on *major goal 54: “Create stairs for* *the house to connect the floors"* (S&K, House 1), the girls had to pause *sub-goal 165 ("placing the selected stairs in the ground floor")* and then spend 11 minutes of gameplay making changes to the structure and arrangement of the existing furniture on the first floor, setting a number of sub-goals (sub-goals 166 – 173) so as to be able to overcome the issue of the game's restrictions and place the stairs.

The temporary abandonment and in some cases the eventual abandonment of goals during gameplay as a result of a tension between what players wanted to do and what they were restricted to do because of the game's menu availability, rules and constraints, indicates that, despite the open-world and sandbox nature of *The Sims* 3 as a game, the gameplay that players experience is still bounded by the rules and constraints that the creators of the game developed (Crawford, 2003; Salen & Zimmerman, 2003). It appears that players' gameplay was bounded, whether this was because of some insurmountable rules and constraints that they faced or because they were not able to interpret and devise a way to overcome some of the issues that they faced because of the rules and constraints they encountered during their gameplay.

Apart from examining the numbers of the major goals and sub-goals that were set by the players during their gameplay and their level of achievement, it was also important to explore the way those sub-goals emerged and were processed during their gameplay. The section that follows will present results related to the third and fourth stage of analysis; sub-goals initiation and process and players' type of talk.

5.3 Sub-goals' initiation / processing and players' type of talk

During the third stage of analysis, players' sub-goals were analysed in more depth. It was important to understand the way the players' sub-goals were initiated and also the way they were processed by players in order to be achieved (paused and/or abandoned) in order to answer the fourth research question: *How do players' goal-directed actions emerge during The Sims 3 gameplay?* (See Section 1.2, in p.5). Thus, this section presents results from all groups in respect to the way those sub-goals were initiated and processed, as coded using the adapted model of Saxe's (1991) emergent goal parameters (third stage of analysis, see Section 3.5.2.3, p.74) and Mercer's (2010) type of talk (fourth stage of analysis, see Section 3.5.2.4, p.77).

Saxe's three parameters that were adapted during this stage of analysis were Conventions/Artefacts, Prior Understandings and Social Interaction. As explained earlier in Section 3.5.2.3 (p. 74) the *Conventions/Artefacts parameter* involved the *Game's Virtual Artefacts (GVA)* such the game's default menu items and options, the *Players' Virtual Artefacts (PVA)* such as items the players had already created and/or placed in their house, the *Game Restrictions (GR)* such as the game's pop-up error messages and *Cultural Conventions and Artefacts (CCA)* such as players' referring to the game's currency. The Prior Understandings parameter involved players' *Everyday Prior Understandings (EU)* and *Mathematical Prior Understandings (MU)* that players brought into gameplay and also *Game's Prior Understandings (GU)* of the game's mechanics of this particular game.

The Social Interaction parameter involved the players' interaction with each other. For this reason, the player who initiated each sub-goal was noted and their type talk was coded whilst processing each sub-goal. Their talk was coded using Mercer's (2010) three types of talk: *Disputational (DISP), Cumulative (CUM)* and *exploratory (EXPL)* talk. However, it is worth mentioning that they were a few sub-goals that were not explicitly initiated by a specific player and a few sub-goals where players' talk was either absent (None) or only one of the players was talking (Other – Monologue) or could not be clearly identified as one type of talk and therefore was marked as *Combinations of talk (Cum./Expl./Disp.).*

This section is divided in two sections; first, in Section 5.3.1 I will refer on the analysis of the way players' sub-goals were initiated and processed in respect to Saxe's adapted emergent goal model; second, in Section 5.3.2 I will specifically refer on the analysis of the way players collaborated during their House 1 and House 2 gameplay. In order to illustrate the results of this section I prepared two comparative tables which present the number of sub-goals that each code was marked during the analysis of the way the groups' sub-goals were initiated (Table 5-5) and processed (Table 5-6). The two tables provide basic descriptive statistics of the frequencies that each code/item occurred during the analysis of the data. However the frequencies and percentages that are presented on those two tables are important in order to highlight patterns of players' gameplay and help the presentation of the results of this section.

The two tables are presented in the next two pages and then the two Sections follow. The results presented in Section 5.3.1 are structured in terms of Saxe's Conventions / Artefacts and Prior Understandings parameters, whereas Section 5.3.2 is structured in terms of each group's collaboration and talk and it involves elements of Saxe's Social Interaction parameter and Mercer's types of talk.

Saxe's codes (sub-goals Initiation)	M & C		A&E		G&N		S&K	
	H1	H2	H1	H2	H1	H2	H1	H2
Total number of sub-goals	**129**	**58**	**95**	**48**	**102**	**42**	**185**	**54**
Conventions / Artefacts Parameter								
GVA	**33 (26*)**	**3 (5)**	**52 (55)**	**11 (23)**	11 (11)	**5 (12)**	**50 (27)**	**13 (24)**
PVA	4 (3)	0 (0)	4 (4)	0 (0)	**15 (15)**	2 (5)	19 (10)	1 (2)
CCA	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	1 (2)
GR	3 (2)	1 (2)	0 (0)	0 (0)	2 (2)	3 (7)	10 (5)	3 (6)
Prior Understandings Parameter								
MU	0 (0)	1 (2)	1 (1)	0 (0)	0 (0)	0 (0)	3 (2)	0 (0)
EU	0 (0)	0 (0)	3 (3)	0 (0)	11 (11)	1 (2)	23 (12)	8 (15)
GU	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)
Social Interaction Parameter								
Player's name that initiated the sub-goal	M:47 (36) C:68 (53) R:6 (5)	M:24 (41) C:31 (53) R:2 (3)	A:51 (54) E:22 (23) R:2 (2)	A:28 (58) E:16 (33) R:3 (6)	G:51 (50) N:36 (35) R:14(14)	G:29 (69) N:12 (29) R:2 (5)	S:77 (42) K:60 (32) R:6 (3)	S:25 (46) K:14 (26) R:2 (4)

Table 5-5: Saxe's parameter codes – Sub-goal initiation

*In brackets is the percentage of each code in respect **to the total number of sub-goals** for each H1 and H2 gameplay of each group (i.e. GVA code was coded in 33 of the total 129 sub-goals in H1 (M&C) and the percentage 26% in brackets was calculated as follows: 33/129 *100% ≈ 26%)

Saxe's codes (sub-goals Processing)	**M & C**		**A&E**		**G&N**		**S&K**	
	H1	H2	H1	H2	H1	H2	H1	H2
Total number of sub-goals	**129**	**58**	**95**	**48**	**102**	**42**	**185**	**54**
Conventions / Artefacts Parameter								
GVA	**129 (100*)**	**56 (97)**	**95 (100)**	**48 (100)**	**98 (96)**	**34 (81)**	**140 (76)**	**54 (100)**
PVA	45 (35)	20 (34)	61 (64)	10 (21)	55 (54)	16 (38)	83 (45)	13 (24)
CCA	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	3 (2)	2 (4)
GR	19 (15)	8 (13)	13 (14)	2 (4)	9 (9)	7 (17)	34 (18)	2 (4)
Prior Understandings Parameter								
MU	15 (12)	33 (57)	6 (6)	38 (79)	8 (8)	31 (74)	26 (14)	27 (50)
EU	66 (51)	37 (64)	64 (67)	40 (83)	54 (53)	**34 (81)**	76 (41)	32 (59)
GU	0 (0)	0 (0)	0 (0)	1 (2)	0 (0)	0 (0)	4 (2)	2 (4)
Social Interaction Parameter (Talk) – Mercer types of talk (2010)								
Cumulative Talk	**61 (47)**	**30 (52)**	**58 (61)**	**27 (56)**	**58 (53)**	**24 (57)**	**137 (74)**	**31 (57)**
Exploratory Talk	20 (16)	20 (34)	27 (28)	20 (42)	30 (27)	17 (40)	39 (21)	18 (33)
Disputational Talk	13 (10)	2 (3)	1 (1)	1 (2)	3 (3)	0 (0)	0 (0)	2 (4)
Combinations of talk (Cum./Expl./Disp.)	9 (7)	4 (7)	0 (0)	0 (0)	9 (8)	1 (2)	4 (2)	0 (0)
None (no talk)	13 (10)	2 (3)	9 (9)	0 (0)	10 (9)	0 (0)	5 (3)	3 (6)
Other (Monologue)	13 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 5-6: Saxe's parameter codes and type of talk – Sub-goal processing

* (129/129 *100% ≈ 100%)

5.3.1 How were players' sub-goals initiated and processed during gameplay?

Overall, most of players' sub-goals were initiated by players orally, through their talk. As shown in Table 5-5, while analysing each sub-goal I noted the initial of the players' name who explicitly (orally) formed that particular sub-goal. There were sub-goals which were initiated by the researcher and were marked as 'R' and there were also sub-goals which were not explicitly initiated by the players or the researcher. Rather such sub-goals were identified through players' actions and might have been initiated by other parameters (codes). In addition, in almost all sub-goals, players talked to each other whilst processing those sub-goals. This was somewhat expected considering that players played this game using one computer and one mouse. Their interaction and talk will be analysed in more detail in Section 5.3.2 in p.147.

Apart from their talk, it appears that most of the sub-goals were initiated and processed with actions that involved the game's virtual artefacts such as the menu's content and menu's options. Furthermore, players' everyday and mathematical prior understandings were also used by players in order to process many of the sub-goals, especially in House 2 gameplay. Examining the numbers and percentages of the codes in Table 5-5 and Table 5-6.

I made some observations that are worthy of commenting, in respect to the way the conventions and artefacts and players' prior understandings influenced the initiation and process of the four groups' sub-goals. These observations are explored below.

5.3.1.1 Sub-goal initiation and processing: Conventions / Artefacts

- ***Game's Virtual Artefacts (GVA code)***

Most of the sub-goals in all groups (except G&N's H1 gameplay) in both House 1 and House 2 gameplay were initiated and processed with actions that involved the *Game's Virtual Artefacts* – GVA. As explained earlier, those artefacts included default elements of the game, such as the game's menu, options and so on. When comparing the numbers of GVA code in House 1 and House 2 gameplay in Table 5-5, it appears that the number of players' sub-goals that were initiated by GVA in House 2 decreases. This means that in House 2 gameplay there were less sub-goals that were initiated by the game's virtual artefacts, such as the Buy mode menus for example. But why was that observed? Perhaps, this decrease might have occurred, because in House 1 gameplay players were not aware of the game menu's content. Thus, their exploration of the game's menus, perhaps influenced their gameplay as this initiated additional sub-goals, i.e. as groups were browsing through the menu to see what was available they set a new sub-goal. It is worth highlighting that, for example, in A&E's House 2 gameplay, the only code that was marked (apart from their talk) was the GVA code when examining the initiation of the groups' sub-goals. Furthermore, looking at Table 5-6, the numbers and percentages of GVA code in processing the sub-goals are high. In fact, more than 76% of the sub-goals in all groups were processed with actions that involved GVA. This increase in the overall percentages in all groups was perhaps expected because in order for players to be able to build or delete something from their houses they needed to use the game's menus and also the menu options. In fact, A&E group had all of their sub-goals processed with actions that involved the game's virtual artefacts in both House1 and House 2 gameplay. However, reviewing the sub-goals that were coded with GVA code in House 1 and House 2 gameplay of all groups, I noticed that GVA code was mostly coded in combination to other codes and in particular with codes related to their prior understandings. More specifically, the times where GVA code was coded as the only one initiating or processing a sub-goal were for operation-related actions such as creating/deleting a wall, clicking on menu items, removing an item from the house and playing with their Sims in Live mode.

- ***Players' Virtual Artefacts (PVA code)***

The numbers and percentages of the *Players' Virtual Artefacts* (PVA) code in the groups, presented in both Table 5-5 and Table 5-6, show that the younger aged groups, G&N and S&K, had 15% (n=15 ≈ 15% of G&N's H1 sub-goals) and 10% (n=19 ≈ 10% of S&K's H1 sub-goals) of their House 1 gameplay sub-goals initiated with actions that were influenced by their previously placed virtual artefacts respectively. The older aged groups, M&C and A&E, on the other hand, had only 3% (n=4 ≈ 3% of M&C's H1 sub-goals) and 4% (n=4 ≈ 4% of A&E's H1 sub-goals) of their House 1 sub-goals initiated by their previously placed virtual artefacts respectively. In addition, in House 2 gameplay, all groups' number and percentage of PVA codes decrease. In fact M&C and A&E had none of the House 2 sub-goals coded with PVA code. This means that the younger aged groups, S&K and G&N, were perhaps influenced by their own, previously chosen or placed, virtual artefacts when they were setting new sub-goals. For example, as mentioned earlier, when furnishing their bedrooms in House 1 gameplay, Stella and Katerina created a dashed wall that separated their bedrooms. Later on, when creating the dining room, they recalled the specific pattern of the dashed wall and explicitly stated that they wanted to create the same.

The latter observation, however, does not mean that the observed difference in the PVA numbers (Table 5-5) in the older and younger groups' coding is due to the groups' age. In particular, examining the way their sub-goals were processed as shown in Table 5-6, all groups' PVA numbers and percentages increase in comparison to the numbers and percentages presented in Table 5-5. In fact, M&C and A&E's PVA codes which were not coded at all in analysing the initiation of the sub-goals, were coded in analysing the processing of their sub-goals in House 2 gameplay in 34% (n=20 ≈ 34% of M&C's H2 sub-goals) and in 21% (n=10 ≈ 21% of A&E's H2 sub-goals) of those sub-goals respectively. In addition, even though the numbers and percentages of the PVA code, as coded in processing the sub-goals, decrease in House 2 gameplay (except M&C's gameplay which increase), the lowest percentage is 21% (A&E in H2) and the highest percentage reaches 64% (A&E in H1). This might mean that players' virtual artefacts that were already placed in their houses, were perhaps an important element in influencing the processing of the players' sub-goals.

For example, in A&E's House 1 gameplay, the processing of the sub-goal: *"Decide where to place the entrance door"* (Sub-goal 83, A&E, House 1) was influenced by the allocation of the rooms (see Figure 4-8 earlier, p.99) and the fact that they had not placed the living room in the area they had initially planned to have as the entrance area of the house (PVA). Thus they had to make adjustments to the swimming pool in order to make entry points for the house (Sub-goals: 84-87 and Sub-goal 92, A&E, House 1) and achieve the major goal 22: *"Place an entrance door"*.

- ***Game's Restrictions (GR code)***

Furthermore, in all groups, except A&E, there was at least 1 sub-goal that was initiated because of a *Game's Restriction* (GR). The groups' GR codes were mostly coded when players were working on a goal and the game displayed an error for which players had to act on. This resulted in players' setting new sub-goals in order to either overcome the obstacle or abandon their initial goal. Examples of such game restrictions were previously described in Section 5.2 p. 134 from both M&C and S&K's House 1 gameplay. However, in House 2 gameplay, for example in M&C's and G&N's gameplay, such game's restrictions involved the unavailability of menu items in Buy mode because there were not sufficient funds in the family's budget balance. In fact, the only GR code M&C had in House 2 gameplay was when they initiated a sub-goal to do something so as to increase the budget *because* of the unavailability of the menu items.

Nevertheless, game's restrictions (GR) also appeared whilst players were processing their sub-goals. Table 5-6 shows that whilst players were processing the sub-goals, they also faced some issues in relation to restrictions that were set by the game and its mechanics. Most GR codes were coded in House 1 gameplay. This indicates that some of the players' actions were influenced by the game's restrictions. For example, during their House 1 gameplay M&C, A&E and S&K groups experienced game restrictions whilst processing 15%, 14% and 18% of their sub-goals respectively. Nonetheless, GR code percentages decrease in House 2 gameplay (except from G&N's gameplay), enhancing the argument that players became more experienced in House 2 gameplay. Therefore perhaps in House 2, players understood the way the game's mechanics and rules worked.

Reviewing more closely the sub-goals of all groups that were coded with GR, these restrictions were related to players' virtual artefacts. More specifically players' artefacts initial placement in the house was obstructing the placement of a new artefact. For example, in A&E's gameplay, most of the game's restrictions and errors that Alexia and Eleni came across in House 1 (10 of the 13 sub-goals in A&E, House 1, see Table 5-6) were related to the arrangement of their previously added artefacts. One such example was when the girls were processing Sub-goal 85: *"Place an entrance door in the living room"* which was a sub-goal that emerged while the girls were processing Sub-goal 83 (see the example that was described earlier in PVA section in p.133). In Sub-goal 85, the girls needed to place a door in the living room but because there was a lamp right behind the area they wanted to place the door and the game displayed the error: *"Can't intersect with other objects",* they had to rearrange the items in the living room so as to add a door. In addition, similar examples were noted from all groups as they all faced game restrictions. For example, when M&C were trying to place a swimming pool in their first house, when A&E were trying to place the entrance points of their first house, when G&N wanted to place an entrance door in their first house and when S&K were trying to place the stairs for their first house. As explained earlier, some of those restrictions in fact resulted in players abandoning their sub-goals.

- ***Cultural Conventions and Artefacts (CCA code)***

Lastly, it appears that none of the sub-goals set by M&C, A&E and G&N during their gameplay, were initiated or processed by *Cultural Conventions and Artefacts* (CCA). CCA was in fact only coded in Stella and Katerina's gameplay when the girls were working on the dining rooms of their houses in both House 1 and House 2 gameplay. Nonetheless, as mentioned earlier, the codes that are grouped in the Conventions/Artefacts parameter were often coded in combination to other codes that involved players' prior understandings which will be illustrated next.

5.3.1.2 Sub-goal initiation and processing: Prior Understandings

- ***Everyday Prior Understandings (EU code)***

Examining the results presented in both Table 5-5 and Table 5-6, it appears that players set sub-goals which were mostly influenced by the game's and their own artefacts and also through their oral talk. However, looking at the younger groups (G&N and S&K), it appears that their *Everyday Prior Understandings* (EU) influenced their setting of new sub-goals as well. Specifically, as presented in Table 5-5, during House 1 gameplay, it appears that G&N set 11 sub-goals (11% of G&N's H1 sub-goals) and S&K set 23 sub-goals (12% of S&K's H1 sub-goals) that were influenced by their Everyday Prior Understandings (EU), whereas the older in age groups, M&C and A&E, set 0 and 3 sub-goals (3% of E&A's H1 sub-goals) respectively. Again, this does not mean that the observed differences in those numbers are because of the groups' age difference. As shown in Table 5-5, the numbers of the EU codes decrease in House 2 gameplay for all groups (M&C's EU codes were 0 in both House 1 and House 2 gameplay and S&K's EU percentage increases from 12% to 15% in House 2 gameplay). Perhaps this was because players recalled the way a real life house is structured as guidance for setting their sub-goals in House 1 gameplay in order to familiarize themselves with the structure and appearance of a virtual house in the game. Thus, in House 2 gameplay, since players had already created a house during their House 1 gameplay, perhaps were not directly influenced by their everyday prior understandings.

Moreover, examining the numbers and percentages presented in Table 5-6, it appears that the overall numbers and percentages of EU code are increased in comparison to Table 5-5 results for all groups. This indicates that players were processing their sub-goals with actions that involved their everyday prior understandings. In contrast to the initiation of the sub-goals, the numbers and percentages of EU codes as shown in Table 5-6 increase in House 2 gameplay, in comparison to House 1 gameplay's numbers. This, perhaps, means that when players were creating the house for the family they had chosen, they were using their everyday prior understandings more often in order to process their sub-goals in House 2 gameplay (In Table 5-6: M&C: 51% in H1 to 64% in H2, A&E: 67% in H1 to 83% in H2, G&N: 53% in H1 to 81% in H2 and S&K: 41% in H1 to 59% in H2).

- ***Mathematical Prior Understandings (MU code)***

Even though the initiation of the players' sub-goals was to some extent influenced by the players' Everyday Prior Understandings, this was not the case for *Mathematical Prior Understandings (MU).* In fact, the few MU codes that were marked in some of the groups (initiation) mostly involved instances where players set sub-goals related to arranging the way specific furniture, lamps and windows were placed in their house. However, when examining the processing of the players' sub-goals, as presented in Table 5-6, it appears that the numbers and percentages of the MU code increase for all groups in comparison to Table 5-5 numbers. In addition, it appears that in all groups, the numbers and percentages of the MU code highly increased when comparing House 1 and House 2 gameplay for all groups. In particular, as shown in Table 5-6, in M&C's gameplay, the percentage of the sub-goals that were marked with MU code in House 1 gameplay was 12% but it increased in 57% in House 2 gameplay. Similarly, in A&E's gameplay the MU code percentage increased from 6% to 79% in House 2, in G&N's gameplay, from 8% to 74% and in S&K's gameplay from 14% to 50%.

These observed increases are important for two reasons. First, it suggests that players' mathematical prior understandings were mostly employed whilst players were processing the sub-goals they had initiated. This suggests that players used their mathematical prior understandings mostly in order to process and achieve their sub-goals rather than setting them. Second, the fact that there is a notable increase of the numbers and percentages of MU code in processing House 2 gameplay sub-goals, in all groups, perhaps implies that when players were constrained to build a house for a specific family and, therefore, were constrained by a specific budget, they had to use their mathematical prior understandings more often in order to process and achieve their sub-goals. Indeed, as it will be presented in more detail in Section 6.1.2.1 (p.159) of Chapter 6, most of the MU codes that were marked in House 2 gameplay were related to the budget's balance, the cost and value of the furniture and other menu items.

- ***Game's Prior Understandings (GU code)***

Even though the initiation of the players sub-goals was to some extent influenced by the players' Everyday Prior Understandings and to a much lesser extent by the Mathematical Prior Understandings, this was not the case for *Game's Prior Understandings (GU)* which seem to have influenced players sub-goals' initiation in a minor extent (less than 2% of the sub-goals). In fact, as shown in Table 5-5 the only GU code was marked in S&K's House 1 gameplay and involved the girls' explicit understanding of the way the game allows players to place some items (i.e. a sink) on top of another item (i.e. bench) and therefore leading to the set of a sub-goal of creating an embedded furniture. In addition, as illustrated in Table 5-6, the only groups that had GU code marked were A&E (n=1 ≈ 2% of H2 sub-goals processing) and S&K (n=4 ≈ 2% of H1 sub-goals processing and n=2 ≈ 4% of H2 sub-goals processing). These instances were the ones related to the understandings of the way the 'Create a Style' option and also the 'Eyedropper' option worked in the game and will be presented in more detail in Section 6.2.2.5 in p. 181.

5.3.2 Players' interaction and talk in House 1 and House 2 gameplay

Overall, all groups managed to jointly create two houses in *The Sims* game. The groups shared similarities and also had differences in respect to their interaction with each other throughout their gameplay. In this section I present the results that are related to the fourth stage of analysis, which was the analysis of players' talk and also link those results to the open codes and categories that were related to players' interaction as they occurred during the first stage of analysis (see Section 5.1.2 in p.128). The following four Sections in this section present the results of each group separately, in relation to players' interaction and talk.

5.3.2.1 Marios and Christina's interaction and talk

M&C managed to jointly create the two houses. However, their collaboration had several levels. As indicated by the results of the third stage of analysis that are presented in Table 5-5, Christina was the one suggesting their next moves, especially in House 1. Indeed, 68 of the 129 (53%) sub-goals were initiated by Christina whereas 47 (36%) were initiated by Marios[1] in House 1 gameplay whereas in House 2 gameplay, 31 (53%) of the 58 sub-goals were initiated by Christina and 24 (41%) sub-goals by Marios. In addition, during their House 1 gameplay, the most frequently occurring open code was *8.2 Disagreements between players regarding their choices* (see Table 5-2 in p. 128). Such disagreements are also evident via the analysis of their talk which is presented in Table 5-6. There were 13 of 129 (10%) sub-goals in House 1 where their talk was marked as *Disputational* and this is something that it is worth highlighting, especially considering that players needed to build a joint house. In addition, while processing 13 sub-goals they did not even talk to each other whereas in another 13 sub-goals they were having a monologue because they were creating their individual bedrooms at that time (*Other Talk*). Nonetheless, as shown in Table 5-6, in 61 of 129 (47%) and in 20 of 129 (16%) sub-goals, their talk was marked as *Cumulative* and *Exploratory*, respectively. This means that in most of their gameplay in House 1, M&C, eventually agreed on most

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[1] 6 sub-goals were initiated by the researcher as a result of players asking for the researcher's suggestions on how to proceed in their gameplay and 8 sub-goals were initiated as a result of previously set sub-goals that were paused during their gameplay.

of their actions and to a less extent negotiated and justified their suggestions, in order to successfully achieve their sub-goals, despite their disagreements.

Furthermore, in House 2 gameplay, which was budget-constrained, M&C's *Disputational Talk* decreased in 3% (n=2 ≈ 3% of overall 58 sub-goals in H2), *None* and *Other Talk* dropped in 3% (n=2 ≈ 3% of overall 58 sub-goals in H2) and 0% respectively in contrast to their *Exploratory Talk* which was increased as it was marked as 34% (n=20 ≈ 34% of overall 58 sub-goals in H2). This implies that M&C did not have instances of 'individual' work in House 2 gameplay. The results of the first stage of analysis presented in Table 5-2 (Section 5.1.2 see p.128), also support the increase of a more explanatory nature of talk between them, as the code *8.2. "Explanation of choices/suggestions"* increased from 7% (n=12 ≈ 7% of overall 161 codes in H1) to 11% (n=17 ≈ 11% of overall 153 codes in H2). In fact this code was the most frequently occurring open code for this group in House 2 gameplay. Thus, in House 2 gameplay M&C had less incidences of disagreements and more incidences of agreements whilst collaborating.

5.3.2.2 Alexia and Eleni's interaction and talk

Overall, A&E collaborated well together in order to create the two houses. In House 1 gameplay, Alexia initiated 51 (54%) and Eleni 22 (23%) of the 95 sub-goals and in House 2 gameplay Alexia initiated 28 (58%) and Eleni 16 (33%) of the 48 sub-goals (Table 5-5). As can be seen in Table 5-6 the girls had only 1 sub-goal in House 1 gameplay, in which their talk was marked as *Disputational* and the majority of their talk was marked as *Cumulative* (n=58 ≈ 61% of H1) and *Exploratory* (n=27 ≈ 28% of overall 95 sub-goals in H1). It is worth mentioning that the *None* (no talk) type of talk which was coded in 9 sub-goals in House 1 involved actions that were relevant to the building of walls, adding wallpapers and furniture that they had already agreed previously during their gameplay. In contrast to M&C gameplay, here, A&E's 'no talk' occurred when they had already agreed on a way to proceed and not for individually creating part of the house.

A&E experienced the least incidences of disagreement in their gameplay in comparison to the other groups. It is worth noting that as shown in Table 5-2 (Section 5.1.2 see p.128), the code 8.1 "*Disagreements between players regarding their choices"* was rarely marked (n=1 ≈ 1% of overall 115 codes in H1; n=2 ≈ 2%

of overall 113 codes in H2). Even though Alexia was the one mostly initiating their next actions, Eleni was not just passively agreeing to what Alexia was suggesting but rather, as indicated in Table 5-5 and in Table 5-6 the girls negotiated the progress of their gameplay together by explicitly explaining and justifying their suggestions. More specifically, as it is shown in Table 5-6, the sub-goals that were coded as involving *Exploratory Talk* between the girls during House 2 gameplay, were 20 (n=20 ≈ 42% of overall 48 sub-goals in H2) and the sub-goals involving *Cumulative Talk* were 27 (n=27 ≈ 56% of overall 48 sub-goals in H2). In addition, code *8.2. "Explanation of choices / suggestions"* was the most frequently occurring code in House 1 gameplay and it was one of the most frequently occurring codes in House 2 (Table 5-2, see Section 5.1.2 in p.128). This, perhaps, suggests that A&E worked together well and – especially in House 2 gameplay – this collaboration involved explaining and justifying their suggestions and eventually creating their two houses in a jointly accepted way.

5.3.2.3 George and Nikos' interaction and talk

Similarly to the other groups, George and Nikos managed to jointly create the two houses. Nonetheless, as shown in Table 5-5, George was the one initiating most of their activity. In addition, even when Nikos was controlling the mouse, George was instructing him on how to proceed. As it was presented in Table 5-2 (see Section 5.1.2 in p.128) earlier, they boys had disagreements regarding their choices in House 1 gameplay but they were explaining their suggestions as well. Specifically, open code *8.1 Disagreements between players regarding their choices* was the most frequently occurring code and the *8.2 Explanation of choices / suggestions* open code was the 2nd most frequently occurring code in House 1 gameplay. This exchange of ideas and disagreements between the boys is also supported by the type of talk results shown in Table 5-6. During House 1 gameplay, the boys' *Disputational Talk* was marked in 3 sub-goals and there were 10 sub-goals where the boys did not even talk, similarly to Marios and Christina's gameplay. It is worth mentioning that 8 of those 10 sub-goals where the boys did not talk were related to furnishing their individual bedrooms. Nonetheless, in the majority of the sub-goals in House 1 gameplay, the boys shared *Cumulative Talk* (n=58, ≈ 53% of overall 102 sub-goals in H1) and *Exploratory Talk* (n=30, ≈ 23% of overall 102 sub-goals in H1). There were 9 sub-goals (n=9 ≈ 8% of overall 102 sub-goals in H1) in House 1 gameplay where their talk was a combination of *Disputational*/Exploratory and *Cumulative*/*Exploratory Talk*.

However, the boys' *Disputational* and *None* types of talk were not marked at all in House 2 gameplay. Furthermore, the frequency of occurrence of the *8.1 Disagreements between players regarding their choices* open code decreased from 17% (n=27 ≈ 17% of overall 149 codes in H1) in House 1 gameplay to 5% (n=6 ≈ 5% of overall 131 codes in H2) in House 2 gameplay. This shows that players disagreed less in House 2 gameplay. In addition, in House 2 gameplay, the boys' *Exploratory Talk* percentage increased from 23% to 40% (n=17 ≈40% of overall 42 sub-goals in H2) and the *Cumulative Talk* percentage increased from 53% to 57% (n=24 ≈57% of overall 42 sub-goals in H2). However, it is important to recall here that during House 2 gameplay, Nikos was distracted by George's younger brother or was eating snacks and perhaps this was also one of the reasons why their disagreements were less. Nonetheless, the fact that there were no sub-goals in House 2 gameplay that were coded with *None* or *Other* as the type of talk, indicates that the boys did talk to each in order to achieve the major goals and sub-goals during their gameplay.

5.3.2.4 Stella and Katerina's interaction and talk

Overall, the girls worked jointly in order to create the two houses. Stella was the one mostly initiating their sub-goals as 77 (n=77 ≈ 42% of overall 185 sub-goals in H1) and 25 (n=25 ≈ 46% of overall 54 sub-goals in H2) sub-goals were initiated by her in House 1 and House 2 gameplay respectively. Katerina initiated 60 (n=60 ≈32% of overall 185 sub-goals in H1) and 14 (n=14 ≈ 26% of overall 54 sub-goals in H2) sub-goals in House 1 and House 2 gameplay respectively. Similarly to Alexia and Eleni and in contrast to Marios and Christina and George and Nikos' groups, the girls did not have particular disagreements during their gameplay. As shown in Table 5-6, in 137 of the 185 sub-goals (74%) in House 1 gameplay, the girls' talk was coded as *Cumulative* and in 39 sub-goals (21%) as Exploratory type of talk. This is also supported by the open-codes of their gameplay in both Houses (see Table 5-2, Section 5.1.2 in p.128), as the *8.2. Explanation of choices / suggestions* was one of the most frequently occurring codes. In addition, in 4 sub-goals (n=4 ≈

2% of overall 185 sub-goals in H1) in House 1 gameplay their talk was coded as Combinations of *Cumulative* and *Exploratory* type of talk and in 5 sub-goals (n=5 ≈ 3% of overall 185 sub-goals in H1) the girls did not talk at all. Those 5 sub-goals coded with *None* were goals for which the girls had already agreed on what to do in advance, similarly to Alexia and Eleni group. For example when they agreed to furnish the bathroom in a similar manner as the other bathroom, there was no talk whilst furnishing the bathroom. During House 2 gameplay, the type of talk in the majority of their sub-goals was again coded as *Cumulative* (n=31 ≈ 57% of overall 54 sub-goals in H2). The percentage of their talk that was coded as *Exploratory* was increased in House 2 gameplay, as it was coded in 18 of the 54 sub-goals (33%), something that was similarly observed in the other three groups' type of talk coding. Indeed, when building the house for the family in House 2 gameplay, the girls explained their suggestions to each other and shared their rationale more often.

It is important to note that the girls did not have a sub-goal in House 1 gameplay in which their type of talk was coded as *Disputational*. In fact, the girls created and decorated each room of their first house jointly. It was clear that the first house was a virtual house that was meant for them. They were jointly choosing items from the menu in order to furnish the rooms of the house. In contrast to Marios and Christina and George and Nikos' groups, all rooms of the house were somewhat shared. This was also indicated by the fact that the girls did not create their bedrooms as separate rooms. Rather, their choice of not separating their bedrooms with walls (only a dashed wall) and their effort in placing similar furniture, windows, lamps, paintings etc. in both rooms, indicate that they create their bedrooms the same way they jointly created the other rooms of the house. In fact, they were referring to "your bed / my bed" and "your desk / my desk" instead of "your bedroom / my bedroom".

Nonetheless, in House 2 gameplay, there were two sub-goals in which their type of talk was coded as *Disputational*. One of those two sub-goals was when Katerina wanted to buy a car for the family and Stella disagreed saying *"They don't want one"* and thus was abandoned. The second one was when Katerina wanted the family to have a dining room and a dining table because of potential guests (major goal 15: *"Create a dining room"*, House 2). Initially Stella did not want to and said *"No"* without providing any explanation and the girls proceeded with their gameplay without creating one. A couple of minutes later, however, Katerina insisted (major goal 19: *"Create a dining room"*, House 2) and started looking for dining tables in the menu saying *"We will make a dining room"* despite Stella saying *"No, no more stuff"*.

5.4 Summary of players' gameplay, goals, actions and talk

This chapter presented the results that occurred during the first four stages of analysis. Much of the results presented in this Chapter demonstrate the gameplay variations that can be generated by what players choose to do, as a result of the open-world sandbox nature of the "emergence game structure" (Juul, 2002, p.324) that was designed by *The Sims* 3 game designers. The results presented in this chapter illustrated an overview of players' gameplay and also the complex way that players' gameplay unfolded as they were initiating sub-goals (and major goals) and then were processing those sub-goals through actions and talk in order to achieve them or pause and/or abandon them.

The results of the open codes (Table 5-2) and categories (Table 5-3) of the first stage of analysis provided an overview of players' gameplay and indicated that it was mostly characterized by three major elements: i. the *players' interaction with each other* as they were negotiating their actions during gameplay, ii. the *specific content and aims of The Sims 3 game* as it is a game that simulates real life and therefore involves virtual families and houses and iii. the *mathematics-related actions* that occurred during gameplay such as players making comparisons of sizes, values and areas and also arranging and rearranging artefacts in their houses. This highlights the *interaction of players*, their *prior understandings* (everyday and mathematical) and the *game's content* as highly involved elements characterizing all players' gameplay.

Nonetheless, the way players' gameplay unfolded was quite complex. As mentioned earlier (Table 5-4, see Section 5.2, in p.132), there were many goals that the players had set which were complicatedly connected to each other as they were occurring while players were working on a previously set goal. In fact, there were many goals which emerged as 'things that needed to be done' (Saxe, 1991) in order for players to proceed with their gameplay (sub-goals). Those sub-goals were almost double in

House 1 in comparison to House 2, perhaps because players were exploring and familiarising themselves with the game and its rules. In addition, considering that the ratio of Major goals / Sub-goals in House 2 increases in all groups when compared to the respective ratio in House 1 gameplay players were perhaps more focused and more specific in terms of what they wanted to do in House 2 gameplay.

Furthermore, the analysis of the way players' sub-goals emerged and were processed, using Saxe's (1991) adapted model and Mercer's (2010) types of talk, suggested that players' sub-goals were mostly initiated orally by players themselves but were also influenced by elements related to the conventions and artefacts that emerged during gameplay and/or their prior understandings, especially their everyday prior understandings, as it was presented earlier. In particular, as shown in Table 5-5, the game's virtual artefacts appeared to have influenced all players' sub-goal initiation to a great extent, in House 1 and House 2 gameplay. This was anticipated, considering that players were familiarizing themselves with the games' content and menus. In addition, as research indicates, when playing digital games, players' prior gameplay experiences and familiarity with digital games influence the way they interact with new games (see Bourgonjon, Valcke, Soetaert & Schellens, 2010). As illustrated in this Chapter, the younger aged groups were also influenced by their created virtual artefacts and their everyday prior understandings when initiating sub-goals in House 1 gameplay in which the players had less budget constraints. This might mean that the younger players were, in House 1, using their prior understandings of the way a real-life house appears and is structured as example. However, in House 2 gameplay, during which players had to deal with the family's budget constraint, the numbers and percentages of players' oral talk as a parameter of influencing the initiation of the sub-goals remained high but the numbers and percentages of other elements influencing their sub-goal initiation in House 1, were decreased in House 2 gameplay for (almost) all groups. It is worth highlighting that only few sub-goals were initiated by players' mathematical prior understandings.

Moreover, the analysis of the way players were processing the sub-goals they had set during their gameplay (Table 5-6) revealed that players' sub-goals were processed with actions that involved the conventions and artefacts and also their everyday and mathematical prior understandings, echoing Saxe's (1991) parameters of his emergent goals model. In particular, for processing their sub-goals, players mostly used the game's virtual artefacts such as the menus, but this was done in combination to other elements such as their previously created artefacts in the house and their everyday and also mathematical prior understandings. Thus, the processing of those sub-goals during players' gameplay involved a 'blended' employment of several elements. In fact, when comparing the percentages of each code in Table 5-6 in House 1 and in House 2 gameplay, it appears that there is an overall increase of the use of players' prior understandings in order to process House 2 gameplay's sub-goals. What is worth highlighting is the noticeable increase of the percentage of mathematical prior understandings in order to process House 2 gameplay's sub-goals in all groups when compared to the House 1 gameplay's percentage. This increase suggests that, in comparison to the creation of the first house, players used in a greater extent their prior mathematical understandings in order to process the sub-goals they had set while creating the house of a specific Sims family which was constrained by a specific budget.

Lastly, even though each group followed a different pathway to create the houses all groups eventually managed to create the two houses jointly. It appears that in each group there was one player who initiated most sub-goals more often than the other in both houses, yet overall, all players appeared to be engaged in gameplay. There were groups (M&C and G&N) who had disagreements during gameplay and this was implied by the numbers and percentages of their *Disputational talk* (Mercer, 2010) and also the incidences where they did not even speak to each other. However, the overall numbers and percentages of players' type of talk in all groups, indicate that in the majority of the sub-goals that they processed, players talk was coded as *Cumulative* (more than 47%) and *Exploratory* (more than 16%). This means that players overall agreed with each other's suggestions before proceeding their gameplay (*Cumulative Talk*) and in fact, in many cases, they explained their suggestions before reaching a joint decision on the way to proceed (*Exploratory Talk*). In fact, there was an increase in the percentages of the *Exploratory Talk* of all groups in House 2 gameplay, when compared to the percentages of House 1. This means that in House 2 gameplay, which had a budget constraint and it was for a specific family, players collaborated by explaining and justifying their suggestions to each other more often than in House 1 where there were less constraints, limiting at the same time the individual gameplay and the unjustified disagreements.

Chapter 6 that follows focuses on specific episodes from all groups' gameplay that are mathematics related and were selected during the fifth and sixth stages of analysis.

Chapter 6 Mathematics related episodes from players' gameplay

Following the results that were presented in Chapter 4 and Chapter 5, this chapter focuses on the mathematics related elements of players' gameplay and illustrates mathematics related episodes from players' gameplay that were selected during the fifth and sixth stages of analysis (See Sections 3.5.2.5 in p. 78 and 3.5.2.6 in p. 79). This chapter is divided in three major sections. In Section 6.1, an overview of the mathematics that was identified from the results of the first four stages of analysis will be provided. Then in Section 6.2, selected episodes will be presented in more detail. Those episodes are grouped in certain themes that emerged in all groups' gameplay and also in themes that link with the Discussion chapter that follows. Lastly, Section 6.3 provides a summary of the results that are presented in this chapter.

6.1 Mathematics in the first four stages of analysis

During the fifth stage of analysis see (Chapter 3, Section 3.5.2.5 in p. 78), the results of the first four stages of analysis were reviewed in order to identify mathematics related elements of players' gameplay which are presented in this section. First, I will briefly refer to the categories and codes that involved actions relevant to mathematics. Second I will refer to the mathematical prior understandings that were identified whilst analysing the initiation and processing of the sub-goals in House 1 and House 2 gameplay. Lastly, I will illustrate results related to players' mathematical prior understandings and their *Exploratory Talk*.

6.1.1 Mathematics in open codes and categories

The open codes and categories that were emerged during the first stage of analysis highlighted some mathematics related elements, especially in Categories 4 and 5. Reviewing the results of the first stage of analysis, Category 4 *Comparison – Area (space) – Size – Arrangement issues* was one of the most frequently occurring categories in all groups' House 1 and House 2 gameplay (See Table 5-3 in Section 5.1.3, p. 130). This category was merging four codes that were: *comparisons* *(size and/or value), area (space) issues, items' arrangement issues* and *house structure issues*. Category 4 – and the four open codes that formed it – revealed that during all groups' gameplay there were actions such as making comparisons, dealing with area/size issues and also arranging and structuring the house. Additionally, Category 5. *Ways to save money / spend less* was a category that was mathematics related as well, because it involved players thinking of ways for spending less and saving on the family's budget. These gameplay instances mostly involved actions where players were aware and were explicitly considering the family's budget balance. For example, players were making comparisons of the value (cost) of menu items so as to choose a cheaper option and were also structuring their rooms and their house in ways that could be cost-effective for the family's budget. Furthermore, as mentioned earlier (see Section 5.1.2, in p.125), Category 5 was only once coded (0.001% of H1 overall codes) in House 1 gameplay whereas in House 2 gameplay, where players had to handle the family's budget, Category 5 was coded 25 times (5% of H2 overall codes).

6.1.2 Mathematical Prior Understandings (MU)

The first stage of analysis provided a first overview of instances of players' gameplay that were related to mathematics. This section presents players' mathematical prior understandings that influenced players' gameplay in House 1 and in House 2 gameplay. As mentioned earlier (Section 5.3.1.2, p.144), mathematical prior understandings only influenced players' sub-goal initiation into a minor extent. However, the results of the third stage of analysis (See Section 5.3 in p. 135) showed that in all groups, mathematical prior understandings only influenced the way players' sub-goals were processed, especially during House 2 gameplay, as more than 50% (Table 5-6 in p.139) of the sub-goals in House 2 gameplay were processed by actions that involved players' mathematical prior understandings (MU). Whilst analysing the MU-coded sub-goals of all groups, I noticed a connection of those mathematical prior understandings to players *Exploratory Talk*. This connection will be presented in this section as well.

6.1.2.1 Open code analysis of the MU-coded sub-goals (fifth stage)

The sub-goals that were coded with MU code were examined even further during the fifth stage of analysis, in respect to House 1 and House 2 gameplay. I used open codes analysis[2] for analysing those MU-coded sub-goals (initiation and processing) in order to gain an insight of the elements of mathematics that players used during their gameplay. I started with M&C group and ended with S&K group as shown in Table 6-1 below. The following open codes occurred: *arrangement (placement), budget, cost (compare), pattern, rotation, shape, size, space (area),* and *'the same' ('look right')*. There were some open codes that were connected, such as the *Size* in relation to the *Cost (compare)*. However the open code that characterized mostly each sub-goal was used to code such sub-goals. The frequency of occurrence of each code, for each group is presented in Table 6-1 below. The most frequently marked code in House 1 and House 2 gameplay is marked as **bold**, for each group.

Group	**M & C**		**A&E**		**G&N**		**S&K**	
Open Code	H1	H2	H1	H2	H1	H2	H1	H2
Arrangement / Placement	2	3	**4**	3	**4**	1	**8**	0
Budget	0	6	0	2	0	5	0	3
Cost (compare)	0	**22**	0	**30**	0	**19**	0	**20**
Pattern	1	0	0	0	0	0	3	2
Rotation	1	0	0	0	0	0	2	0
Shape	4	1	1	0	0	0	0	0
Size	**8**	5	2	1	2	4	6	0
Space (area)	3	1	0	2	2	2	2	0
'the same' ('look right')	1	1	0	0	0	0	5	2

Table 6-1: Players' mathematical prior understandings – open codes

[2] This MU open code analysis occurred after the inter coder reliability session and therefore was not cross-checked with the inter coder.

Examining the numbers of the open codes in Table 6-1 above, two observations are made. First, looking at the overall numbers of the codes it appears that in all groups (except for M&C), most of the MU-coded sub-goals in House 1 involved issues related to the *Arrangement and/or Placement* of the virtual artefacts in their houses. M&C were mostly having issues with the size of their house (too large) as most of the sub-goals in House 1 gameplay were marked with the *Size* code. Second, in House 1 gameplay, none of the MU-coded sub-goals were coded with the *Budget* or the *Cost (compare)* codes. The *Cost (compare)* code involved players choosing the cheapest option by comparing the value of the items in the menu and the *Budget* code was marked when players were performing actions so as to increase or save on the family's budget. However, in House 2 gameplay, which was budget constrained, most of the MU-coded sub-goals were coded with the *Cost (compare)* code. In addition, the *Budget* code was also more frequently coded in House 2 gameplay and was the 2nd most frequently marked code (except for A&E group in which Arrangement/Placement was the 2nd most frequently marked code).

The aforementioned two observations suggest that when players were building a house with less budget constraints (House 1 gameplay) they were not explicitly considering the cost of the items they were buying for their house. When they were building a house with budget constraints (House 2 gameplay) however, the mathematical prior understandings that they used were influenced by the family's budget and its constraint. Thus, players were more cautious in House 2 gameplay as they compared the cost of several menu items (such as furniture) before buying them and were also thinking of ways to save on the budget. This is also supported by the results of the first stage of analysis (see Table 5-2 in p.128), in which the frequency of occurrence of the open code *4.1 Making comparisons (size and/or value)* was increased from 3% (n=17 of the H1 overall codes) to 9% (n=44 of the H2 overall codes) and also by the increase of Category 5 *Ways to save money / spend less* frequencies in House 2 gameplay that was discussed earlier in Section 6.1.1.

Furthermore, there were open codes, as shown in Table 6-1, that occurred in only one or two of the groups. For example, S&K and M&C were the only groups that were coded with *Pattern*, *Rotation* and *'the same' ('look right')* codes in their MU-coded sub-goals. In addition, M&C and A&E were the only groups that were coded with *Shape* code. Although episodes of those sub-goals will be presented in Section 6.2 later on, a brief description of those three codes is needed. *Pattern* code was coded in instances where players were trying to apply a certain pattern – usually – whilst decorating their houses. *Rotation* code was coded in instances where players were explicitly rotating a virtual artefact so as to help them achieve their sub-goal. *'The same' ('look right')* code was coded when players were explicitly trying to get the same result – usually – in the appearance of the house as they had done previously in their gameplay. *Shape* code was coded in instances where players were manipulating and explicitly talking about the shape of a virtual artefact. Lastly, all groups were coded with the *Space* (*area*) code which involved instances where players were talking about furnishing certain – usually empty – areas of their house.

6.1.2.2 MU-code combinations in sub-goals

In Chapter 5 (Section 5.3 in p.135), I presented the way players' sub-goals were initiated and processed using codes and in this section I isolated and analysed the MU-codes using open codes. Reviewing all those MU-coded sub-goals of the groups I marked the combinations of codes in sub-goals which were MU-coded in order to provide an account of the frequency of those combinations. Table 6-2 that follows presents the several combinations of codes that were coded in the MU-code. The combinations as illustrated in Table 6-2 show that there was not a sub-goal where MU code was coded alone. When MU code was used it was always in combination with at least one other code, during the analysis of the data. This is important because it suggests that, during their gameplay in *The Sims 3*, the mathematical prior understandings that players brought into gameplay were always in interplay with other elements, either their everyday prior understandings, the game's and their own virtual artefacts, the game's restrictions and/or cultural conventions and artefacts.

In addition, although there are some differentiations amongst the groups in House 1 gameplay, the most frequent combination of MU code in House 2 gameplay, as indicated in Table 6-2 below (marked as **bold** and **<u>underlined</u>**) was the MU,EU,GVA (in G&N's case PVA was added to this combination). This suggests that when players' gameplay was more constrained (House 2), players used a combination of MU, EU and the GVA in order to achieve their sub-goals.

Group	**M & C**		**A&E**		**G&N**		**S&K**	
House	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**
Total MU-codes	**15**	**33**	**6**	**38**	**8**	**31**	**26**	**27**
GVA, MU, EU	**<u>5</u>**	**<u>17</u>**	1	**<u>26</u>**	0	12	3	**<u>14</u>**
GVA, MU, EU, PVA	2	3	0	5	**<u>3</u>**	**<u>13</u>**	0	6
GVA, MU, EU, GR	0	1	1	0	0	2	0	0
GVA, MU, EU, PVA, GR	1	1	**<u>2</u>**	1	0	0	1	0
GVA, MU	3	6	1	4	1	1	3	3
GVA, MU, PVA	2	3	1	1	0	1	**<u>7</u>**	1
GVA, MU, GR	1	0	0	0	1	1	0	1
GVA, PVA, GR, MU	1	1	0	1	2	0	0	0
MU, PVA	0	0	0	0	1	0	**<u>7</u>**	0
MU, GR	0	0	0	0	0	1	0	0
MU, EU, GR	0	0	0	0	0	0	1	0
MU, EU, PVA	0	1	0	0	0	0	3	0
MU, EU, PVA, CCA	0	0	0	0	0	0	1	2

Table 6-2: MU code combinations in all sub-goals

In addition, reviewing the combinations of the MU-coded sub-goals I isolated the ones which were coded with EXPL type of talk as well. Table 6-3 below presents the several combinations and frequencies of codes that were coded with the MU code in sub-goals which were coded with *Exploratory* type of talk. In respect to House 2 (more constrained) gameplay, it becomes clearer that in most of the times when players used *Exploratory* type of talk to process sub-goals that required them to use their mathematical prior understandings, they also used their everyday prior understandings and the game's virtual artefacts (combination MU,EU,GVA marked as **bold** and **<u>underlined</u>**).

Group	M & C		A&E		G&N		S&K	
House	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**
Total MU&EXPL-codes	**5**	**14**	**3**	**17**	**0**	**14**	**7**	**13**
GVA, MU, EU	1	**6**	0	**13**	0	**5**	1	**5**
GVA, MU, EU, PVA	1	1	0	2	0	5	0	3
GVA, EU, MU, GR	0	0	1	0	0	1	0	0
GVA, PVA, GR, MU, EU	0	1	**2**	1	0	0	1	0
GVA, MU	1	2	0	0	0	1	1	1
GVA, MU, PVA	0	1	0	0	0	1	0	1
GVA, MU, GR	1	0	0	0	0	1	0	1
GVA, PVA, GR, MU	1	1	0	1	0	0	0	0
MU, PVA	0	0	0	0	0	0	**3**	0
MU, GR	0	0	0	0	0	0	0	0
MU, GR, EU	0	0	0	0	0	0	0	0
MU, PVA, EU	0	1	0	0	0	0	0	0
MU, EU, PVA, CCA	0	1	0	0	0	0	1	2

Table 6-3: MU code combinations in sub-goals that were coded as Exploratory Talk

6.1.2.3 MU-coded sub-goals and Exploratory Talk

The results in Chapter 5 earlier showed that, while players were processing their sub-goals, the percentages of the Mathematical Prior Understanding (MU) code in House 2 gameplay were increased. Similarly, players' *Exploratory Talk* (EXPL) percentages were also increased in House 2 gameplay (see Table 5-6, in p.139). Thus, I isolated all the MU-coded sub-goals and all the EXPL-coded sub-goals of all groups. From those sub-goals, I isolated the ones that were coded with both MU and EXPL (MU&EXPL). I then calculated the percentage of the MU&EXPL-coded sub-goals in respect to the total sub-goals of each group, the percentage of the EXPL-sub-goals that were also coded with MU code and the percentage of the MU-coded sub-goals that were also coded with EXPL code as shown in Table 6-4 below.

Examining Table 6-4, I made three observations which are worthy of commenting. First, the percentages of the MU&EXPL-coded sub-goals in House 1 gameplay were rather low as less than 4% of the overall sub-goals in all groups were coded with MU&EXPL. However, in House 2 gameplay, the percentages of the MU&EXPL codes increase and reach a range of 24% - 35% of the overall sub-goals in all groups' gameplay. Second, the percentage of the EXPL-coded sub-goals that were MU&EXPL-coded (% of MU&EXPL in Total EXPL) increase noticeably in House 2 gameplay for all groups. Third, the percentages of the MU-coded sub-goals that were MU&EXPL-coded (% of MU&EXPL in Total MU) also increase in M&C, G&N and S&K groups but in a less extent. In A&E group, this percentage decreases slightly.

Group	**M & C**		**A&E**		**G&N**		**S&K**	
House	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**
Total sub-goals	**129**	**58**	**95**	**48**	**102**	**42**	**185**	**54**
EXPL code	20	20	27	20	30	17	39	18
MU code	15	33	6	38	8	31	26	27
MU&EXPL code	5	14	3	17	0	14	7	13
% of MU&EXPL in Total sub-goals	4%	24%	3%	35%	0%	33%	4%	24%
% of MU&EXPL in Total EXPL	25%*	70%	11%	85%	0%	82%	18%	72%
% of MU&EXPL in Total MU	33%	42%	50%	45%	0%	45%	27%	48%

Table 6-4: Mathematical prior understandings code and Exploratory Talk

*MU&EXPL-coded sub-goals were 5 in M&C H1. The percentage of MU&EXPL-coded sub-goals in respect to the total number of EXPL-coded sub-goals is 5/20 * 100% ≈ 25%

The three aforementioned observations indicate that when players were engaged in a constrained gameplay (House 2 gameplay) their use of mathematical prior understanding in processing sub-goals that involved players' *Exploratory Talk* (MU&EXPL) increased. The three observations also suggest that, in a constrained gameplay, most of the sub-goals that players processed with *Exploratory Talk* involved players' prior mathematical understandings but not more than half of the sub-goals that involved players' prior mathematical understandings were processed with *Exploratory Talk*. Indeed, there were many sub-goals, such as for example sub-goals that involved players selecting the cheapest available option for their house in House 2 gameplay, where players used their mathematical prior understandings but their talk was coded as *Cumulative*. However, when players' talk was *Exploratory* in House 2 gameplay, players were mostly using their mathematical prior understandings in order to process such specific sub-goals. Nonetheless, in order to acquire a greater understanding of this MU – Type of talk relationship, I isolated the MU-coded sub-goals in which players' talk was coded as *Cumulative*, similarly to Table 6-4 earlier. The results are shown in Table 6-5 below.

Group	**M & C**		**A&E**		**G&N**		**S&K**	
House	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**
Total sub-goals	**129**	**58**	**95**	**48**	**102**	**42**	**185**	**54**
CUM code	61	30	58	27	58	24	137	31
MU code	15	33	6	38	8	31	26	27
MU&CUM code	8	14	3	21	4	17	19	12
% of MU&CUM in Total sub-goals	6%	24%	3%	44%	4%	40%	10%	22%
% of MU&CUM in Total CUM	13%*	47%	5%	78%	7%	71%	14%	39%
% of MU&CUM in Total MU	53%	42%	50%	55%	50%	55%	73%	44%

Table 6-5: Mathematical prior understandings code and Cumulative Talk

*MU&CUM-coded sub-goals were 8 in M&C H1. The percentage of MU&CUM-coded sub-goals in respect to the total number of CUM-coded sub-goals is 8/61 * 100% ≈ 13%

Despite the fact that my initial hypothesis before making this analysis was that MU&CUM percentages would not increase in House 2, as shown in Table 6-5 above, they did. Nonetheless, as shown in Table 6-4 earlier, in House 2 gameplay, the percentage of the EXPL-coded sub-goals where MU&EXPL was coded was more than 70% in all groups, whereas the respective percentage for CUM-coded sub-goals, as shown in Table 6-5 is, for some groups (M&C and S&K) less than 50%. This will be further discussed in Chapter 7 (see Section 7.1.3, p.216 and Section 7.3, p.233).

Recaping the results presented and analysed in Section 6.1, it appears that, overall, players drew on their mathematical prior understandings in order to build their two houses. Whilst processing their sub-goals in more constrained gameplay (House 2), players interacted with each other and the game's virtual artefacts, negotiating their actions through their talk in their effort to understand the game's rules and constraints and explore the relationships that were buried in the game's virtual artefacts. Overall, in House 2, players were talking about and manipulating the artefacts' properties that were related to their gameplay, such as GVAs' cost and size. In situations where they encountered issues that required them to negotiate their next steps, setting emergent sub-goals (Saxe, 1991) and in 'breakdown moments' (Noss, Hoyles & Pozzi, 1998, p.108), players explored their options using *Exploratory* type of talk (Mercer, 2010) and employed their mathematical prior understandings in order to reach a decision and proceed. Employing mathematical prior understandings in order to solve problems in educational settings and in real life is a longterm aim of Mathematics Education (European Commission, 2011; NCTM, 2000). In addition, several researchers focused on the affordances that real-life artefacts have in enabling children in mathematics' classrooms to make connections to real life, drawing on information they could get from those artefacts (see Bonotto, 2013; Monaghan, 2016b). Nonetheless, the challenges that players in my research encountered and the artefacts that they interacted with during gameplay were not artefacts and tools that can be found and used in mathematics' classrooms. Rather, during gameplay, players manipulated game artefacts that stimulated their thinking and enabled them to employ their mathematical prior understandings in order to proceed with their gameplay. The following section of this chapter will present mathematics related episodes from players' gameplay, most of which were coded with MU and EXPL codes.

6.2 Selected episodes from all groups' gameplay

The selected episodes that are presented in this section were isolated during the fifth and sixth stages of analysis and come from all groups' gameplay. These episodes are grouped in five themes, in order to help the reader and also the Discussion chapter that follows. They were selected and grouped this way, guided by the open code analysis of the MU codes that was illustrated in Section 6.1, highlighting cost, budget and size appeared to be frequent in players' gameplay. In addition, the selected episodes presented in this section involved players' *Exploratory Talk*. The themes are: *i. Comparing sizes – Dealing with excessive size of House 1* (Section 6.2.1)*, ii. Saving on the budget* (Section 6.2.2) *iii. Dealing with a low budget – Increasing the budget* (Section 6.2.3), *iv. Considering the family members and their needs* (Section 6.2.4), and *v. Group-specific episodes* (Section 6.2.5). Each Section (theme) that follows is structured in a similar manner; first there is an overview of the theme and then, for most of the episodes, a brief description of the respective players' gameplay, a detailed analysis of the major goals and sub-goals that were involved and the respective extract of the players' talk.

6.2.1 Comparing sizes – Dealing with excessive size of House 1

All groups created a larger house in House 1 gameplay in comparison to House 2 gameplay. However, two of the groups appeared to have some issues with the large areas of the house that were left 'empty', even after furnishing the rooms. M&C and G&N placed an unusual number of the same furniture to 'fill in the empty space' of certain rooms. Both groups realised the large size of their house once they started furnishing it and comparing the size of the furniture to the size of the room. As mentioned earlier in Chapter 4, A&E compared their house's size to the neighbour's house and eventually created a smaller house. In addition, the fact that they furnished each room before building the next one perhaps helped them keeping their house's size smaller. Furthermore, despite their large house's size, S&K did not place extra furniture just to 'fill in the space'.

There are three episodes in this section. First, an episode from M&C's gameplay in which they were trying to fill in the 'extra space' in the kitchen. Second, an episode from G&N's gameplay where they decided to place benches in their kitchen to fill in the 'extra space'. Lastly, an episode from A&E's gameplay during which they compared the size of their house to the neighbour's house.

6.2.1.1 M&C – Making the kitchen's table bigger (House 1)

This episode comes from M&C House 1 gameplay, during their 2nd meeting, when they were furnishing the kitchen of the house (Major goal: 20). They added a kitchen table from the menu but when they placed it in the kitchen room they said that they wanted a bigger one. They selected other tables from the game's menu but there was not a bigger table in the menu so they decided to attach tables to the existing one in order to make it bigger (Sub-goal 63, see Table 6-6 below). However, the game's mechanics do not allow some items to be attached as there needs to be some space between them for *The Sims* virtual characters to move and this was the case with their actions to attach multiple tables: there was some space between the tables which was something that they did not like, so they paused that sub-goal and moved on to the next sub-goal which was adding sinks for the kitchen. They did not explicitly state that they had abandoned this sub-goal nonetheless.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
11:00 – 12:43 (M2[3])	20. Furnish the kitchen	63. Make the table bigger by attaching tables *(Paused)*	EXPL	M	GVA PVA GR MU
15:28 – 17:50 (M2)	21. Decide what to do with the rest of the kitchen area	68. Add more tables on the existing one to make it look bigger *(Achieved)*	EXPL	C	GVA MU PVA

Table 6-6: M&C sub-goals 63 and 68: Making the table bigger (House 1)

A few minutes later they had returned to this sub-goal, but this time, as a sub-goal of a different major goal 21: *"To decide what to do with the rest of the kitchen area"*. They decided to make the table *look* bigger because there was too much space left empty in the kitchen area. So they added two more tables, despite the fact that there was space left between them and 8 chairs around the three tables (Figure 6-1). The related extracts of both sub-goals 63 and 68 *Exploratory Talk* are presented next.

Sub-goal 63:

C: This one (table from menu)

M: Add it to see how big it is.

C: It's big (adds it in the kitchen) … or maybe not?

M: No, we need a bigger one. Attach it.

---

[3] M2 indicates that the recording of this part was on the 2nd meeting of players' gameplay.

C: Oh, to make it bigger?

M: No, attach another table next to it.

C: To become bigger?

M: Yes (Christina tries to attach another table but there is space between the tables)

M: Oh, we can't

C: Should we add a different table?

M: I think so (They go through the menu). No this one is better for the living room and it's not bigger than the other one.

(They select a sink from the menu and add it on the existing bench)

[…]

Sub-goal 68:

C: So, what are we going to do with all this space then?

M: Which?

C: All this! (Christina shows the kitchen area)

M: Should we add a wall and make another room?

C: Hm… Can't we attach this one? (Christina selects the same table they had added in the kitchen and adds two more tables in parallel to the existing one and then 8 chairs around the three tables)

M: OK, it looks good now.

C: Yes, should we add a lamp there?

M: Yes (they move on to add lamps).

Affected by their previously made actions and the creation of a quite large-sized kitchen, M&C faced some issues in this episode. Here, M&C used their mathematical prior understandings (MU) for adding multiple tables of the same kind that they had already been manipulating (PVA), so as to overcome the game's restrictions (GR) and get their desired bigger table.

Figure 6-1: M&C – Making the table bigger

Another aspect of this episode is the fact that sub-goal 63 was paused and then reoccurred as sub-goal 68 after a couple of minutes of gameplay but as part of a different major goal; Sub-goal 63 aimed in making the kitchen table bigger whereas sub-goal 68 emerged as a solution to the issue of having a large kitchen area being left empty and aimed in making the kitchen table *look* bigger so as to 'fill' in that space. Marios suggested reducing the size of the kitchen but Christina insisted in making the kitchen table bigger, even if that meant attaching overall 3 tables, that had space between them and surrounding them with 8 chairs to look like one big table. This was something they did with other room areas of House 1 as mentioned earlier; added 4 toilets in the bathroom, added 4 TVs next to each other and so on. This was one of the reasons why House 1 had a very high furnished value.

6.2.1.2 G&N – Furnish the kitchen (House 1)

Similarly to Marios and Christina, George and Nikos created a large kitchen room during House 1 gameplay. When they were furnishing the kitchen (Major goal: 25) and were adding benches (sub-goal 60, see Table 6-7) they decided to place 16 benches overall because they wanted to have many benches to cook and use them in party occasions for their guests. They did that because they wanted to fill in the kitchen's space.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
1:12:20 – 1:17:30 (M1)	25. Furnish the kitchen	60. Choose and add benches *(Achieved)*	EXPL	G	GVA PVA EU MU

Table 6-7: G&N – Sub-goal 60: Choose and add benches (House 1)

The related extract of sub-goal 60 *Exploratory Talk* is presented below:

G: Shall we place a bench? This one?

N: Yes. Put many benches

G: Many? We only need one.

N: No, not just one, it's too small. Put many benches. We need more

G: Why?

N: To cook.. we need many. Put many one next to the other.

G: Like this? (G places 3 benches one next to the other)

N: Yes but put more all the way until the fridge.

G: How many? Three are enough

N: No, look, the kitchen has too much space, put more to cover the wall. We need more

G: OK, we can have party (they laugh)

N: Yes and we can stand behind them and have the customers there

G: Customers?

N: Guests.

George and Nikos decided to add 16 benches of the same kind attached, instead of 1or 3 benches that George initially suggested because they wanted to cover the length of the kitchen's wall (MU) that they had already created (PVA). They referred to their kitchen as sometimes being a party – area with customers – guests (EU). As shown in Figure 6-2, having a lot of benches in the kitchen was not the only 'unusual' part of their house. The boys created three toilet/bathrooms in the ground floor. Perhaps this was also done because they had a lot of areas in their house that seemed empty.

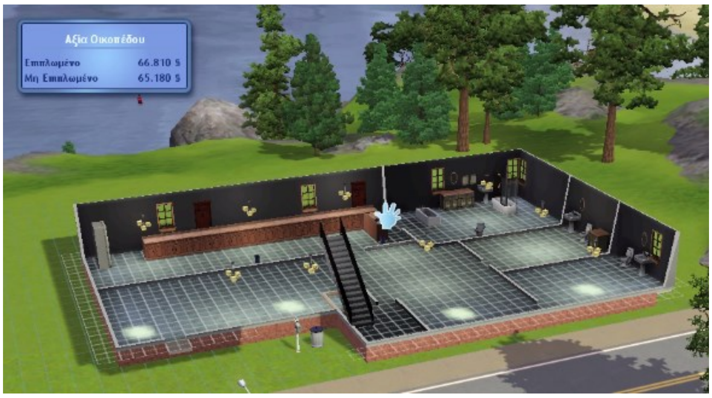

Figure 6-2: G&N – Sub-goal 60 – Placing benches (House 1)

As seen in Figure 6-2 the boys could have created the bedrooms in the ground floor as well, but they did not because as they stated they wanted to have two levels in their house. The boys could have deleted some of the rooms but did not. Instead, they decided to use them as bathrooms/toilet rooms and eventually created a house which had 5 bathroom/toilet rooms overall.

6.2.1.3 A&E – Comparing sizes – The neighbor's house (House 1)

This episode comes from Alexia and Eleni's House 1 gameplay. The girls created the foundations of their first house and questioned whether the house was too small. Then, they zoomed out the camera (see also Figure 4-7 earlier) and compared the size of their foundations to the size of the neighbour's house. They then decided to expand the foundations so as to make their house larger. This was sub-goal 3 of House 1: *"Expand the foundations"*. Table 6-8 below shows the detailed analysis of this particular sub-goal.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
07:50 – 09:49 (M2)	2. Create the foundations	3. Expand the foundations *(Achieved)*	EXPL	GVA MU A	GVA PVA (AA)

Table 6-8: A&E sub-goal 3: Expanding the foundations (House 1)

The extract of their *Exploratory Talk* that took place while they were working on sub-goal 3 was:

A: Do you think it's good?

E: I think so… I don't know. How about the other houses?

(Alexia zooms out the camera and they laugh)

A: Well, I think we need to make it larger

E: Yes we do. Can we add more on these ones? (asks the researcher)

AA (Researcher**)**: Yes, just drag the mouse and add whatever you want

(Alexia drags the mouse to create three more columns of foundations next to the existing ones but she has some difficulties handling the mouse)

A: Hmmmm. You do it!

E: OK. (Eleni holds the mouse and adds the foundations. Then zooms out the camera again) I think it's OK now.

A: Yes.

In order to confirm that their house's size was "good", the girls used the neighbour's house as a point of reference (GVA) in order to get an idea of the size of the houses in *The Sims 3* game. They did not measure the size of the neighbour's house but they estimated visually (MU) that their house's foundations (PVA) needed to be expanded. The other three groups in this research did not compare their first house's size to the existing Sims houses that were in the game before building their house. This comparison of the house's size to an existing Sims house, perhaps, guided this group to create the smallest house in House 1 gameplay and also the cheapest one (furnished value) of all the four groups.

6.2.2 Savings on the budget

When building their second house in House 2 gameplay, players had to build and furnish that house within a specific budget. This section illustrates five episodes of all groups' gameplay that highlight the several ways the players made choices that saved on the family's budget. First, all groups explicitly stated that they would create a smaller house due to the budget. Second, all groups compared the cost of the menu items before buying them and chose a cheap, and most of the time the cheapest available, option. Third, even though in House 1 gameplay, all groups chose a lot of furniture and appliances (and as shown in the previous section, M&C and G&N chose many of the same kind) to equip their house, in House 2 gameplay they all made choices that can be characterized as *'what was necessary'* for the family. Fourth, during their gameplay, some groups made some cost-effective decisions so as to save on the budget. Lastly, fifth, S&K and A&E used the *'Create a Style'* option and saved on the family's budget whilst decorating their house.

6.2.2.1 M&C – House 2 – Making a small(er) house

M&C's intentions were stated early in their gameplay as they both agreed in selecting a small lot:

> **M:** We should do a small house. This one is small (the lot).
>
> **C:** Yes, it's small. This one (§1800) or this one (§2400)? This one I think (§1800)
>
> **M:** Yes, it's small and good!

They also stated that they would create a small house:

> **C:** We should do it small like this, so as to… to do smaller and then we see what we can do outside.
>
> **M:** Anyway, we should do a normal house this time and it should have a ground floor only.
>
> **C:** Yes, no upper floor, it's more expensive.

This intention of making a smaller second house was something that all groups explicitly stated in the beginning of their House 2 gameplay.

6.2.2.2 M&C – House 2 – Comparing cost/value

Apart from creating a small house in a small lot, Marios and Christina, were also selecting cheap furniture and decorations for this house. Sub-goal 10 of House 2 (Table 6-9) is an example of comparing prices and selecting a cheaper option.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
1:09:01 – 1:10:32 (M2)	5. Create the ground floor (tiles)	10. Choose and place tiles for the bathroom *(Achieved)*	EXPL	M	GVA (menu) MU EU

Table 6-9: M&C – Sub goal 10 (House 2) – Choose and place tiles for the ground floor

As can be seen by their *Exploratory Talk* in the extract below, Marios and Christina made their decisions for the bathroom tiles thinking about the cost (GVA and MU) and also the nature (EU) of the specific room:

> **M:** What tiles should we put in the bathroom?
>
> **C:** This one?

M: Do you mean this one? (Marios shows the same tile)

C: No, that's 10(§). It's expensive isn't it?

M: Yes true. How about this one? (shows a wooden tile that is §4)

C: Yes that's good. But wait… it's a bathroom, don't we need bathroom tiles?

M: You are right, how about this one? (Marios shows a tile that is §4)

C: Yes, that's 4(§) too, it's good.

M: Yes this one (Marios add the tiles in the bathroom).

Comparing the cost of the items they were selecting for House 2 was something they were doing quite often as it was seen earlier in Table 6-1. They wanted to select cheap options but they were not always selecting the cheapest ones. For example, in the extract above, they could have selected the cheapest option of tiles that the game has in the menu which was free (§0) but they did not explore the entire tile menu of the game at that time. There were also times, such as whilst processing sub-goal 10 above, where apart from choosing a cheap option, they based their decision on the type of room they were creating; in real life, wooden tiles are avoided for a bathroom because of the humidity. Similarly to Marios and Christina, all other groups were also making such comparisons before buying something for the house. S&K and A&E in fact, used – mostly – the free options for wallpapers and tiles which resulted in saving a lot on the family's budget.

6.2.2.3 A&E – House 2 – Choose what is necessary (comparing cost/value)

It was highlighted earlier that in Alexia and Eleni's House 1 gameplay, the girls paid attention to their house's appearance and chose the house's furniture, wallpapers, tiles and other items from the menu, mostly in respect to what *'looked nice'* for their house. In House 2 gameplay, however, the girls had different criteria in mind when furnishing the family's house and this was because of the budget and *The Sims* family. The following extracts of their gameplay illustrate the way they considered the cost of several items that they used to furnish and decorate House 2; Sub-goals: 12 and 23.

- *Sub-goal 12: Select and place the cheapest available wallpapers*

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
27:01 – 29:20 (M2)	8. Decorate the bedroom	12. Select and place the cheapest available wallpapers *(Achieved)*	EXPL	A	GVA EU MU

Table 6-10: A&E – Sub-goal 12: Select cheapest available wallpapers (House 2)

Sub-goal 12 emerged when the girls wanted to add wallpapers to decorate the bedroom of the house (Table 6-10) and they started looking for the cheapest available option in the menu and, as they explicitly stated, a free option:

> **A**: And to think, we haven't even placed wallpapers yet
>
> **E**: They don't need them now. If we have enough money then we will add wallpapers… They are unemployed.
>
> **A**: Ummm… Does the menu have zero? (Alexia enters the wallpaper menu and places the mouse over several wallpaper designs)
>
> **E**: Check
>
> **A**: It doesn't…
>
> **E**: Go on, we'll find zero somewhere (they reach the §0 valued wallpapers of the menu)
>
> **A&E**: There!
>
> **A**: This one
>
> **E**: Yes, since it's free (they laugh. Alexia places the free wallpapers in the bedroom)
>
> **A**: It looks ancient but, what to do? They are unemployed!
>
> **E**: It's fine!

It is worth mentioning that later on, the girls used §0 valued wallpapers and tiles for the rest of the house's walls decoration.

- *Sub-goal 23: Select and place the cheapest option for sink and bench*

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
39:12 – 41:26 (M2)	10. Furnish the kitchen	23. Select and place the cheapest option for sink and bench *(Achieved)*	EXPL	A	GVA EU MU

Table 6-11: A&E – Sub-goal 23: Select cheapest option for sink and bench (H2)

It appears from their talk and actions during their gameplay that the girls wanted to furnish the kitchen (and the rest of the house) with the cheapest available and most necessary furniture. Sub-goal 23 (see Table 6-11) provides an example of such thinking as can be seen in the extract of their talk below:

> **A**: What else? Do they need a dishwasher?
>
> **E**: Ummm, it's not necessary. They can wash the dishes manually. It will cost more if we add a dishwasher. We can add a sink
>
> **A**: OK (Alexia clicks on the sink – menu). So we need a sink, the cheapest
>
> **E**: Basically a sink and a bench with a sink…
>
> **A**: What do you mean? I think we should add a simple sink (stand-alone) and a bench next to it… (Alexia adds the cheapest sink, §120)
>
> **E**: Ummm…
>
> **A**: So as to place the dishes to dry (Alexia selects the cheapest bench from the menu, §140)
>
> **E**: I thought of something but I don't know how much it will cost
>
> **A**: What?
>
> **E**: Add the bench (Alexia places a bench next to the sink). I want to see something and if it doesn't work we can click undo and we'll get our exact money back
>
> **A**: OK, what?
>
> **E**: How about… Click on the sinks that don't have a bench (embedded sink) and… (Alexia clicks on all embedded sinks) no they are more expensive (the cheapest is §150 – and much smaller) and we need a bench too so no.
>
> **A**: No, it's cheaper this way.

Here, the girls not only selected the cheapest available options for furnishing the kitchen, but they also discussed the cost-effectiveness of their selection by: a. referring to the necessity of adding a dishwasher or provide a cheaper solution (sink) for the family to wash the dishes (EU), b. comparing the cost of the sink with the other available sinks (GVA and MU) and c. comparing the cost of an embedded sink with a sink and a bench placed separately and making a decision (GVA and MU).

Nonetheless, the girls did not do that in all items they had placed in the house. For example, in Sub-goal 37: *"Place an entrance door for the house"*, the girls did not select the same type of door they had been selecting for the rooms of the house. Rather, they selected a more expensive one (a double door) because as Alexia said and Eleni agreed: *"It's the front entrance door"*. All groups chose a more expensive door for their house's front entrance.

6.2.2.4 Making cost-effective decisions on the house's structure

During their House 2 gameplay, the groups that did not face difficulties with the family budget's balance, A&E and S&K, explicitly made some cost-effective decisions while creating their house's structure. The following two episodes are from A&E and S&K House 2 gameplay when the girls were shaping the walls of the rooms after explicitly thinking of ways to save on the budget.

- **A&E – Sub-goal 11: Shape the walls of the room**

The girls created a hallway in House 1 (PVA) which separated the rooms of the house so as not to be attached. During the building of their second house (House 2 gameplay), the hallway (EU) option that was suggested by Alexia, was rejected by Eleni, explaining that this would cost them more (MU) as they would need to add extra walls and doors (GVA). As shown in Table 6-12 below, this was sub-goal 11 which emerged while the girls were working on major goal 7: *"Create another room"* in House 2.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
26:30 – 27:00 (M2)	7. Create another room	11. Shape the walls of the room *(Achieved)*	EXPL	E	GVA EU MU PVA

Table 6-12: A&E – Sub-goal 11: Shape the walls of the room (House 2)

The extract of the girls' talk in this particular incidence is presented next.

> **A**: We need some space here to do a hallway again
>
> **E**: Ummm, wait no. Listen, do them attached and this way we will not need extra doors
>
> **A**: Ummm
>
> **E**: I mean, if you attach it (the other room) here (to the existing wall) then we will not need two walls. It will cost more if we put a hallway. We will also need more doors.

A: You are right

Figure 6-3: A&E – Sub-goal 11: Shape the walls of the room (House 2)

Thus, the girls were considering a cost-effective structure of the house so as to save on the overall family's budget.

- **S&K – Sub-goal 20: Break wall as entry point for kitchen**

While Stella and Katerina were creating the kitchen room in their 2nd house they were talking about their budget's balance. They decided to select cheap light options (Sub-goal 19*: "Choose and place cheap lights for the kitchen"*) for their kitchen and also, instead of having a door, to break walls so as to create the entry point for the kitchen (Sub-goal 20: *"Break walls to create entry point for the kitchen")* and save on the budget, as shown in Table 6-13 below.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
2:32:16 – 2:35:02 (M2)	12. Create the kitchen	19. Choose and place cheap lights for the kitchen *(Achieved)*	EXPL	K	GVA (menu) EU MU (cost)
		20. Break walls to create entry point for the kitchen *(Achieved)*	EXPL	K	GVA (delete) PVA EU MU

Table 6-13: S&K – Sub-goals 19 and 20: Creating the kitchen (House 2)

The extract of their respective *Exploratory Talk* is provided below. Right before choosing the lights, the girls had a brief talk regarding their budget.

S: We had twenty thousand and now we are left with 10 comma five hundred four. How much did we spend?

K: Ummm, wait, we had twenty thousand. Right? So, minus what we are left with, which is ten thousand five hundred four. So we used nine thousand four hundred ninety six… Oh I will cry.

S: Yes and imagine, not furnished is the 9 comma four hundred and five. And furnished is a hundred thousand…

K: We will only do a small living room here

S: …and a toilet and that's it.

K: Now lights. Not these ones…the cheap ones (K enters the light menu and selects a §95 lamp)

S: Is this the cheapest?

K: No, it's a bit more expensive, it's 95 but it does a really good job, but in the other rooms we can use the cheapest (§45)

S: Wait, use these (§45).

K: Wait wait, I'll click undo to get our money back (K clicks undo).

S: Now select the cheapest (K selects the §45 lamp). See? It also does a good job

K: Wait, wait, don't add more. We need to add doors. Oh I know! Let's break walls like in the other house.

S: And she'll see him getting undressed? Are you crazy?

K: No, not in the bedrooms, in the kitchen!

S: Oh, OK. (K deletes two columns of wall and the girls get §212 as refund because they accidentally deleted the kitchen's bench as well)

K: We got money back see?

S: And look at all this light that comes in? Perfect.

After talking about their budget's balance and choosing – eventually – the cheapest (MU) available lamp (GVA) for their kitchen so as to have light (EU), Stella and Katerina made a cost-effective decision regarding the entry point of their kitchen. Katerina suggested that the girls would delete part of the kitchen's wall (PVA) so that they will not need to add a door and, therefore, spend more money (MU). In fact, the girls got refund for deleting the walls (they accidentally deleted a bench as well). The girls, nonetheless, added doors in the bedrooms and the toilet as they explicitly referred to the virtual characters' privacy (EU). From their talk regarding the budget balance, it appears that Stella experienced some difficulties in reading the five digit numbers of the balance, whereas Katerina could quite easily read the numbers and also making the subtraction to answer Stella's question. Additionally, it appears that the girls were aware of the budget's balance indicator and also the furnished and unfurnished value of their house.

6.2.2.5 Use of 'Create a Style' and 'Eyedropper' option

S&K and A&E wanted to decorate their second house but most decorative options in the game were expensive so they both used the 'Create a Style' option of the game to change the appearance of their existing artefacts. In addition, S&K also used the 'Eyedropper' option so as to decorate the floor of the rooms. The following two episodes are from S&K and A&E gameplay.

- **A&E – use and reuse of the 'Create a Style' option**

Alexia and Eleni were not happy with the appearance of the cheap items they had selected for House 2. In fact they explicitly shared their dislike throughout the House 2 gameplay with expressions such as: *"This is ugly"*, *"This looks ancient"*, *"Aren't there any other colours of free tiles? These are not good"*. When the girls had finished building House 2 and they explicitly stated that they had enough money (MU) in the family's budget left, they were thinking of changing the house's appearance. Then Eleni recalled the 'Create a Style' option of the game that they had discovered in House 1 gameplay (see Figure 4-11, in p.102) and she suggested using it (Sub-goal 42: "*Decorate the outside walls of the house*").

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
1:02:52 – 1:18:37 (M2)	17. Decorate the outside of the house	42. Decorate the outside walls of the house *(Achieved)*	EXPL	A	GVA EU GR MU / GU

Table 6-14: A&E – Sub-goal 42: Decorate the outside walls of the house (H2)

The extract of the girls talk while processing sub-goal 42 was:

A: No, we will not leave it (the outside appearance) grey.

E: No, it’s ugly

A: Something that will look good and we can pay for it, we do have money.

E: Stone?

A: This looks good, or maybe this one which is brighter, let’s check (Alexia adds the chosen style decoration - §10 per column - and money is subtracted from the budget)

E: Noooo it costs too much

A: And it’s not even pretty

E: Undo please (They click undo and get the refund)

A: Something that will be pretty and bright

E: I know! Remember when we had the colours changed?

A: Right! You mean this one (They click on the ‘Create a Style’ option and Alexia tries it but it does not work). Oh… No… We have to pay

E: Wait, what if you add a wallpaper and then try it on it?

A: OK, let’s try any wall (Alexia choses a §5 wallpaper and then clicks on the ‘Create a Style’ option and it works) Yeeeeees!

E: Great! Now, wait… wait, try it with something that is free so that we won’t get charged

A: OK, We’ll click undo (Clicks undo) now get the free ones, they are ugly

E: It doesn’t matter, we’ll change it to whatever we want.

A: Yes, and for free. (The girls use the free wallpaper and then spend time in the ‘Create a Style’ menu to change the appearance of the wallpapers)

[…]

A: There! Pretty and bright

E: And for free!

The girls wanted to decorate the house’s walls (EU) but were also concerned regarding the available budget (MU). Recalling the ‘Create a Style’ option that they had discovered in House 1 gameplay (GVA / GU) and despite the restrictions they faced whilst trying it (GR), they eventually used it on a free (§0 cost) style wallpaper in House 2 which allowed them to change the colour and design of the free wallpaper into something that they found *‘pretty’* and *‘bright’* and saving, at the same time, on the family’s budget because it was for free (MU). This was something that Stella and Katerina also did during their House 2 gameplay but they did not use a free style of wallpaper.

- **S&K – use of 'Create a Style' and 'Eyedropper' options**

Stella and Katerina also used the 'Create a Style' option of the game, but unlike Alexia and Eleni, they first came across that option during the building of their second house and, in particular, when they had finished building their house and were playing with their Sims. During that time, the girls were in the Live mode of the game and noticed that their Sims were not happy because the house did not have any wallpapers and was unfinished. Thus, the girls returned to the Buy mode so as to add wallpapers and decorate the house to make their Sims happier (Major goal 23: *"Make The Sims happier").* The girls explored the Buy mode menu and whilst viewing the wallpapers of the game's menu they were concerned regarding the cost. Katerina clicked on the *'Create a Style'* option and once they realized that they could change the appearance for free, they used that option so as to change the colour of the house's floor (they had previously chosen the free option of tiles whilst creating the floors). Nonetheless, similarly to A&E, they could not use it for wallpapers because the 'Create a Style' option did not work on walls without existing wallpapers. So the girls chose cheap wallpapers from the menu and did not use the 'Create a Style' option for the wallpapers after all.

Once the girls changed the colour of the house's floor, they explored the other options available in the menu and discovered the *'Eyedropper'* option of the game while they were trying to decorate the floor of their second house, a couple of minutes after discovering the 'Create a Style' option. The *'Eyedropper'* option of the game works similarly to a copy-paste process. When players use the *'Eyedropper'* option to select something, then the same style of the selected item can be 'pasted' for changing the style of other items. As shown in Table 6-15 below, Sub-goal 49: *"Change the colour of the floor tiles"* and sub-goal 50: "*Create a pattern on the floor tiles"* emerged when the girls realized what the '*Create a Style'* and the *'Eyedropper'* option did.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
3:04:50 – 3:11:12 (M2)	23. Make *The Sims* happier	49. Change the colour of the floor tiles *(Achieved)*	CUM	K GVA (Create a Style)	GVA (Create a Style)
		50. Create a pattern on the floor tiles *(Achieved)*	EXPL	K GVA (Eyedropper)	GVA (Eyedropper) MU

Table 6-15: S&K – Changing the appearance of the ground floor in House 2

Figure 6-4: S&K use of 'Eyedropper' for decorating the floor (House 2)

The extract of the girls respective *Exploratory Talk* is provided below.

K: What's this?

S: Try it (K clicks on the blue coloured floor and then moves the mouse on several parts of the house. As soon as she reaches the purpled coloured bedroom they see that they can copy-paste a style on a tile)

K: Ohhh. Imagine if we can add one by one. Different colour

S: Yes, this is what I was thinking as well. Do it. (K creates checked patterns as shown in Figure 6-4 above). Cool!

K: Yes!

S: Now do the rest

K: OK (K creates the same pattern in the bedrooms and toilet).

S: But we need to change the colour here (living room and kitchen)

K: What do you mean?

S: I mean, it is already blue. It's the same

K: Yes, you are right. How about changing this colour into something lighter

S: But then all floors will change

K: No, no, look, we change just this one with the Style (Create a Style option) and then use the dropper (Eyedropper) to get the blue squares

S: Oh, I see. OK do it. But choose a different colour for the floor, not light blue (K changes the colour of the floor into a purple) and now click with the dropper on one of the blue squares. Yes like this (K clicks on one of the blue squares to copy the style)

K: Now this looks nice (K adds blue squares one by one on the purple main floor in order to create the checked pattern)

S: It looks nice and it's free!

K: Yes, and for free.

In this episode, the girls used the *'Create a Style'* and '*Eyedropper'* options of the game in order to change the appearance of their house's floors, for free. Sub-goal 49 emerged whilst the girls were exploring the 'Create a Style' and sub-goal 50 emerged when the girls were exploring the 'Eyedropper' option. The girls did not face particular trouble understanding what the two options could do and K created the pattern quite easily.

6.2.3 Dealing with a low budget – Increasing the budget

M&C and G&N were the groups that managed to spend the family's budget before finishing the house. Thus, they needed to find ways to increase the budget. There were two main ways they tried to increase the budget: a. sell (delete) furniture and get a full refund and b. delete parts of the house (making the house smaller) and get an almost full refund. The extracts that follow illustrate those two ways as implemented by those groups in their House 2 gameplay.

6.2.3.1 Sell (delete) furniture and other items

Marios and Christina were left with §1867 in the budget and they still needed to furnish the rooms. Christina was worried that they did not have enough money, but Marios said that they had enough. Then Marios suggested deleting more windows (PVA) (Sub-goal: 25) so as to increase the budget (MU) (Major goal: 16) and

Christina disagreed. Marios explained his rationale and then Christina agreed (Table 6-16).

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
1:38:30 – 1:39:53 (M2)	16. Increase the budget	25. Delete more windows *(Achieved)*	EXPL	M	MU PVA EU

Table 6-16: M&C – House 2: Increase the budget (I)

The *Exploratory Talk* extract below shows their talk in this incidence:

> **C:** Still, I don't think we have enough money
>
> **M:** It's enough, it's enough. We should delete these windows here.
>
> **C:** How much do we have now? (Christina means: money)
>
> **M:** We should delete all these windows because there are too many of them.
>
> **C:** No, no, they are good
>
> **M:** No, we will need to hide them later (with blinds). So that's not in our interest
>
> **C:** Hm… Yes, you are right. Delete some but not all!
>
> **M:** OK (Marios deletes some windows). We should delete this one too (kitchen window)
>
> **C:** NO!
>
> **M:** Oh my God! OK

Returning to the operational definition of mathematical thinking (see Chapter 2, Section 2.5, p.43), this extract demonstrates an instance of M&C's mathematical thinking during their gameplay. In this extract, there was a *need* to increase the budget because M&C estimated that the remaining amount of the budget would not be enough for them to finish the house. Whilst considering their options, Marios thought of a way to increase the budget and also save money(MU) in their next moves. He suggested deleting the windows they had already added (PVA) because there were too many but Christina did not agree. In order to convince Christina to delete some of those windows, Marios shared his thoughts by explaining that having many windows will require them to buy buy blinds in order to establish the family's privacy (EU), arguing that the overall cost (MU) was not in their "interest". This was enough for Christina to agree and M&C proceeded with deleting some of the windows, increasing, this way, the budget.

6.2.3.2 Delete parts of the house

- **M&C gameplay**

Even though Marios and Christina managed to increase the budget by selling (deleting) the windows in the previous episode, a couple of minutes later the family's budget balance got very low (§127). They wanted to furnish the bathroom (Sub-goal 32, see Table 6-17) but the game's menu (GVA) showed all (adult) toilets in red: non-affordable (GR code, see Figure 6-5 below). Having a toilet for their Sims was important for Marios and Christina:

> **C:** It's red! Everything is red! (non-affordable)
> **M:** Where are they going to go when they will want to go to the toilet? We don't have enough money to get them one.
> **C:** What are we going to do? Can't we delete everything and start over?
> **M:** I think we should make the house smaller to get more money…I have to go now. Shall we stop and continue next time?
> **C:** OK (they ended gameplay of Meeting 2)

Figure 6-5: M&C – House 2: Unavailable menu items

Thus, once again, they needed to increase the budget (MU) in order to be able to furnish the bathroom which led to Sub-goal 33 (see Table 6-17) but this time, they needed a lot more money to be able to finish the house.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
1:44:18 - 1:46:35 (M2)	19. Furnish the bathroom	32. Choose and place a toilet *(Paused)*	EXPL	C	GVA GR EU MU
04:20[4] – 09:05 (M3)	20. Increase the budget	33. Delete the bedrooms to get more money (and move the beds) *(Achieved)*	CUM	M (sub-goal 32)	GVA EU MU
16:41 – 19:57 (M3)	24. Furnish the bathroom (see 19.)	41. Choose and place the cheapest toilet *(Achieved – see sub-goal 32)*	CUM	M	GVA EU MU

Table 6-17: M&C – House 2: Increase the budget (II)

When they started playing the game again (third meeting), they decided to move the bedroom furniture in the living room and delete the parents' and baby's bedrooms so as to increase the budget (Sub-goal 33). The family's budget then increased to §5009 and they created a smaller room which they decided to be a room for the parents and the baby. They then furnished the bathroom by adding the toilet (sub-goal 41) and other items.

The above episode, apart from showing the ways Marios and Christina found in order to increase the budget it also illustrates the way some sub-goals emerged whilst others were in process and were webbed. In this particular case, sub-goal 33 (and major goal 20) emerged because of the game's restriction that occurred in sub-goal 32 when the budget became lower than the price of the toilet (MU and GVA). But a toilet and the other items that the house still needed to be functional were important for the players and therefore they had to increase the budget so as to be able to proceed with their gameplay.

[4] Marios and Christina decided to finish their second meeting when they were faced with this budget issue (Sub-goal 32) and continued playing in the third meeting.

- **G&N gameplay**

Similarly to Marios and Christina's gameplay, George and Nikos also reached to a point where menu items became unavailable (GR) and marked with red colour, because they did not have enough money to buy them. The boys had already deleted parts of their house earlier in their House 2 gameplay, when they had spent half of the family's budget. However, minutes later, while were working on Sub-goal 17 *("Add benches and sink in the bathroom")*, the boys faced game's restrictions (GR) as they had spent almost the entire budget and most of the items in the menu were unavailable (GR / GVA). Thus, the boys set a new goal, Major goal 12: *"Increase the budget"* and they decided to delete part of the house again (Sub-goal 18, Table 6-18) to increase the budget (MU).

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
47:41 – 49:50 (M2)	11. Furnish the bathroom	17. Add benches and sink in the bathroom *(Paused)*	CUM	G	GR (budget) GVA MU
	12. Increase the budget	18. Delete part of the house *(Achieved)*	EXPL	G GR (budget)	GVA MU

Table 6-18: G&N – House 2: Increase the budget

The boys' respective talk extract is provided below.

G: We are only left with 349! We can't buy a toilet, a bathroom, everything is red. We can't. What should we do?

N: I don't know

G: Should we delete this (shows a part of the house)? Because if we leave it like this they will get crazy, the will not have a place to sit and go around the house like crazy.

N: Delete everything! We should have created a smaller house

G: Not everything (he laughs) just this side to get more money

N: We will never finish this house

G: We will, we will (G deletes part of the house). See? Now we have two thousand six hundred… oh.. now it goes less (G adds the missing walls and money is reduced from the budget).

N: It's better (the budget is §2212)

6.2.4 Considering the family members and their needs

All groups played the Live mode of *The Sims* game when they said they were finished building their second house. Nonetheless, whilst playing the Live mode, all groups realized that their house needed changes so as to be accessible for the family (i.e. placing stairs in the entrance door for their Sims to be able to enter the house) and also so as to make their Sims happier by increasing their mood meter. Earlier, in Section 6.2.2.5 (p.181) I presented the way S&K noticed that their Sims were less happy with their house because the rooms the girls created did not have wallpapers. Thus, the girls paused the Live mode and used the *'Create a Style'* and *'Eyedropper'* options so as to change the appearance of the floor of the house and later on added wallpapers on the walls so as to make their Sims happier.

The three episodes that follow describe: i. the way M&C considered their Sims family needs after viewing their *'needs meter'* and edited their house accordingly so as to increase their Sims' overall 'mood meter', ii. the way A&E considered their Sims characters interests and chose certain menu items and iii. the way G&N considered their Sims characters entertainment needs so as to increase their overall *'mood meter'*.

6.2.4.1 M&C – Making house adjustments to suit *The Sims* mood and needs

When Marios and Christina finished their second house, they shifted to the Live mode of the game in order to play with their Sims family. During that time, they refined the house's items as a result of *The Sims* *'mood meter'* and *'needs meter'*. First, they saw that their Sims *'hunger – need meter'* was lower (GVA) than the others (Figure 6-6, bottom right) and they wanted to command the woman to cook. However, they noticed that they had not added an oven/hob for their Sims family to cook (EU). Thus, they paused the Live mode and then added an oven/hob so as their Sims could cook (Sub-goals 55 and 56, see Table 6-19).

As they continued playing with their Sims they observed that their Sims' mood meter was not full (Figure 6-6, bottom left) because, as shown by *The Sims* mood meter*: "a room was unfinished"* (Figure 6-6, top right missing tiles). Thus, they decided to pause the Live mode of the game and figure out which room was unfinished and finish it.

Figure 6-6: M&C – House 2: Sims mood and need meter

Therefore, in order to make their Sims happier, they added tiles and wallpapers for the new room whilst considering the budget (MU). This increased their Sims mood meter balance (GVA), as their Sims were getting happier (Table 6-19). Even though they wanted to leave the family with money for their future (Christina stated it), they eventually left them with §9 because they decorated that room to make them happier.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
37:40 – 40:48 (M3)	28. Play with *The Sims*	55. Ask the woman to cook something *(Paused)*	CUM	C GVA (need meter)	GVA
		56. Choose and place an oven for the woman to cook *(Achieved)*	EXPL	Sub-goal 55 M	GVA EU
	29. Make *The Sims* happier	58. Finish the decoration of the kitchen (tiles and wallpapers) *(Achieved)*	EXPL	C GVA (mood meter)	GVA MU

Table 6-19: M&C – House 2: Making *The Sims* happier

6.2.4.2 A&E – Considering their Sims' interests

When players selected a family from the inventory of the game, apart from information regarding a family's budget and the level of difficulty playing with that family, players could read information regarding the characters and interests of their Sims family. Alexia and Eleni were the only group who read the information that the game provided for each of their Sims characters and their interests during House 2 gameplay. When furnishing the living room of House 2 the girls explicitly stated that they would add a library (GVA / EU) in the living room because they had previously read in the (man) Sims family member interests (GVA) that he likes reading (Sub-goal 35: *"Choose and place a library for The Sims man"*, Table 6-20).

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
46:02 – 48:14 (M2)	12. Create the living room	35. Choose and place a library for *The Sims* man *(Achieved)*	EXPL	E GVA (family menu)	GVA (menu) EU

Table 6-20: A&E – Sub-goal 35: Place a library furniture for the man

The *Exploratory* extract of their respective talk is provided below.

> **A:** OK, what else is necessary?
>
> **E:** You know what? We need to add a library. Are there any libraries there?
>
> **A:** I don't know, why?
>
> **E:** Because we definitely need to add one for him. Remember? He says he likes to read books.
>
> **A:** Oh, yes right, I forgot. I think it has, it should be in the Office things
>
> **E:** Check (A clicks on the Office items menu) there that one.
>
> **A:** This one is good yes, because he is a classic guy. OK? Happy?
>
> **E:** (laughs) Yes

At that time of gameplay, the girls were talking about items that were necessary in the family's house, as their plan was to buy only what was necessary. Therefore the girls considered this library as 'necessary' because of the man's interests.

6.2.4.3 G&N – Increasing their Sims' entertainment meter

Once they had finished with their second house, George and Nikos played with their Sims in the Live mode and decided to add an entertainment device (EU) for their

Sims family in order to increase their *'entertainment need meter'* (GVA) as they noticed that it was lower than the other meters (Major goal 26: *"Increase entertainment need meter"*, Table 6-21). After talking about several items that they could buy to keep their Sims entertained (EU), they eventually bought a Hi-Fi system because they had almost spent the entire family budget (MU) and therefore they had to buy an affordable option (GR).

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
1:09:00 – 1:11:00	26. Increase entertainment need meter	41. Choose and place an entertainment kind of furniture	EXPL	GVA (mood and need meters) G	GVA EU MU GR (budget) AA (shows)

Table 6-21: G&N – Sub-goal : Keeping *The Sims* entertained

The respective extract of the boys talk is provided below.

G: They need fun (entertainment need meter)

N: Yes, it's little (low)

G: Put a car!

N: Yes (N clicks on the car menu but everything is unavailable and red)

G: Ummm, they are red, we don't have enough money (§372)

N: Oh no

G: Try a playstation (N clicks on the consoles but everything is unavailable)

N: No, nothing (Clicks several items in the menu). Chess?

G: No, not chess. We need to get something, try the speakers (Hi-Fi system)

N: This we can buy, it's not red

G: Yes, get that one and play music.

AA: You can also get them dance if you want.

N: Dance! Yes! (AA shows how to command *The Sims* to dance)

G: They are funny (they laugh), now is more (entertainment needs meter)

N: Yes, nice. Can't they dance… blues?

AA: No, I think they need to go to a dance school to learn how to dance that!

6.2.5 Group-specific episodes

Sections 6.2.1 to 6.2.4 included themes that were shaped from episodes of all groups' gameplay. However, there was an episode that occurred in M&C group and an episode that occurred in S&K group that are discussed in Chapter 7 that follows. These two episodes are presented in this section next.

6.2.5.1 Changing the shape of the swimming pool (House 1) - Shape

This episode comes from House 1 gameplay of Marios and Christina, when they wanted to expand the swimming pool that they had already placed. They wanted to get the same curved effect in both endings of the swimming pool. However, they could not manipulate the menu's sliders and options for concave and convex shape of swimming pools in order to get the shape they initially wanted. Thus, they abandoned the specific sub-goal. This was sub-goal 5 of House 1: *"Change the shape of the swimming pool (and expand)"*. Table 6-22 below shows the detailed analysis of this particular sub-goal.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
25:01 – 27:32 (M1)	3. Create the swimming pool	5. Change the shape of the swimming pool (expand) *(Abandoned)*	EXPL	C	GVA MU GR

Table 6-22: M&C sub-goal 5: Changing the shape of the swimming pool (H1)

This sub-goal was initiated by Christina who wanted to get uncommon shapes for their house. They had already created a curved side of the swimming pool as shown in Figure **6-7** below and they wanted to make the same effect on the other side. However, after exploring the menu's options (GVA) and dealing with some game restrictions (GR) as can be seen in Figure **6-7**, Marios and Christina rotated the extra part of the pool, tried to manipulate the sliders of the pool menu, talked about shapes and what could they do to solve this issue, but eventually decided to abandon this sub-goal.

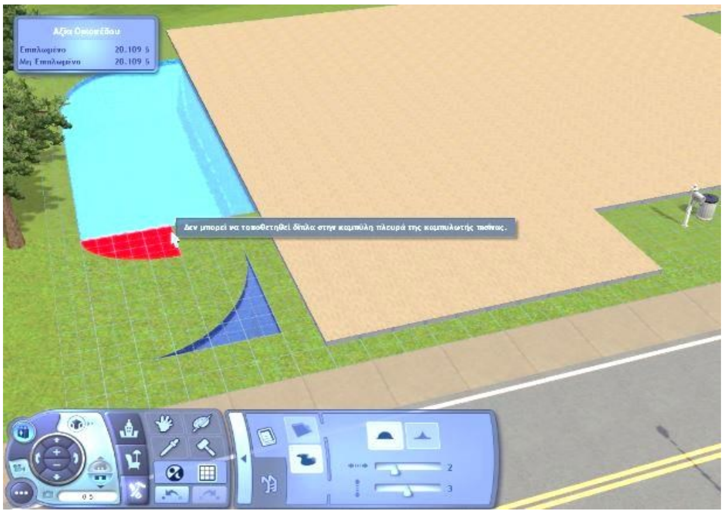

Figure 6-7: Game error/restriction in expanding the swimming pool (M&C)

The extract of their respective *Exploratory Talk* that took place was:

C: Can't we do that one (the other side) the same as we did the other one?

M: OK, how many was that one? (The tiles that the existing curved part of the pool takes, M starts counting the tiles silently) Why don't we delete this and make it even and make a good pool?

C: No, we should do it like this. It is nice to have a curve, it's uncommon.

M: OK, I think we should delete a part of it because it's too elongated.

C: OK

[…] (They try to add a curved swimming pool)

C: But why? (The game marks the pool with red colour)

M: Maybe we need to choose the curved one? (C choses the curved option)

C: Still red… (The game shows red when they try to add the pool)

M: What does it say? *"You can't place next to the curved part of a curved swimming pool"*? I think I got it! Make it bigger (they try the sliders, Christina changes the slider's variable)

C: Like this?

M: Yes it has to be the same as the side of the swimming pool (the game still shows red)… Or maybe it's the other (slider) that we need to make bigger

C: OK, still it's red. *"You can't place…"* (She reads they displayed error) what to do? Should we leave it as it is?

M: I think yes.

Marios and Christina wanted to change the shape (MU) of the swimming pool on one end so as to be the same as the shape they had already created on the other end. To do so, they had to experiment with the curved pool menu sliders (GVA) and rotate the shape in a way so as to be able to connect to the existing swimming pool. They tried to make sense of the errors (GR) the game was showing and they tried to give explanations and suggestions on how to proceed. Marios was right when he suggested "making it bigger" but their input on the slider variables was incorrect. As a result, the game kept showing the same error and Marios and Christina could not understand what they needed to do in order to make it right, perhaps because they did not understand what the terms "curved" and "concave" meant. Eventually they decided to abandon their sub-goal. It is worth mentioning that this sub-goal was the only MU-coded sub-goal that Marios and Christina abandoned during their overall gameplay.

6.2.5.2 S&K – Creating "the same" bedrooms

This episode comes from S&K's House 1 gameplay, when the girls were furnishing the 'office' area of their bedrooms in House 1. As mentioned earlier, (see Section 4.4, p.112), during their first meeting, the girls initially created a house in which the entire first floor was their shared bedroom with bedroom, office, gym and other furniture. Even though the girls eventually changed the structure of the first floor during their 2nd meeting, the episode in which the girls were selecting the same kind of furniture twice and placing them in a way that both bedrooms/offices would look 'the same' was selected for two reasons; firstly, because it is an episode that shows the complex way players' sub-goals emerged during gameplay and secondly, because it illustrates S&K's thinking in respect to making the bedrooms 'the same'.

The following episode occurred after the girls had already placed their beds and small tables in their bedrooms and they had separated those bedrooms with the dashed wall (see Figure 6-8 below) and involves the girls' actions when they started furnishing their 'office' area of their bedrooms (Major goal 31: *"Furnish the office are of the first floor"*). Whilst working on Major goal 31, there were 11 sub-goals (Sub-goals 64 – 74) that emerged. Nonetheless, in this episode the first 6 (Sub-goals 64 – 69) are presented in order to illustrate the way those girls furnished their office areas in their bedrooms (Table 6-23), due to the length constraints of this chapter.

Time	Major Goal	Sub-goal	Talk	Initiated by	Processed by
1:11:41 – 1:16:02	31. Furnish the office area of the first floor	64. Choose an office desk from the menu *(Achieved)*	CUM	K EU	GVA EU PVA
		65. Place the desk opposite the beds and between the windows *(Achieved)*	EXPL	S	PVA MU
		66. Choose and place the same desk *(Achieved)*	CUM	S PVA	GVA PVA MU
		67. Choose and place guitars *(Achieved)*	CUM	K GVA	PVA MU
		68. Choose and place a library in the middle of the desks *(Paused)*	CUM	K GVA	GVA
		69. Move the painting so as to place the library in the middle of the desks *(Achieved)*	EXPL	S PVA	K PVA MU

Table 6-23: S&K – Major goal 31: Furnish the office area of the first floor (H1)

The girls' talk in respect to the above extract of their gameplay is provided below.

S: Now for our offices

K: Yes, which one? (they click on the desks in the menu). This one?

S: No, wait there are colours, choose the white one (K chooses the white).

K: Should we place it here on the wall?

S: Place it in between.

K: Aren't we having one each?

S: Yes. I mean place it here between the windows (K places the desk between the windows on the left side) so that it will be right opposite my bed

K: Oh, OK! I see. And now I do the same… here (chooses the same and places it between the windows on the right side)

S: Yes. What else can we add?

K: Guitars!

S: Yes, which colour? White? White is nice.

K: Yes, now place one here and then the other one on the other side (They place the guitars on the right and left side of the existing painting which is between the desks, see Figure 6-8)

(The girls explore the menu items)

S: How about a library?

K: Yes, a shared one. But… we need to move the painting

S: Yes, we should put it (the library) in the middle for both of us so move it

K: Yes, and we can add another painting on the other side too (K moves the painting on the right side office area and then places the library between the guitars, see Figure 6-8)

Figure 6-8: S&K – Creating 'the same' bedrooms

The girls in this episode, wanted their first floor to be a shared area in which they would create 'the same' bedrooms. The girls first used the windows and the placement of their beds so as to place the desks 'the same' way (MU) and then used the initial position of the painting (which they then replaced with a library) so as to place their guitars 'the same' way. The girls did not make exact calculations in order to furnish (GVA) their bedroom 'the same' way. Nonetheless, they used their previously created artefacts as references (PVA).

6.3 Summary of mathematics related episodes from players' gameplay

This chapter brought together results from all stages of analysis, focusing on the mathematics related elements of players' gameplay. Section 6.1 highlighted the mathematics related elements that were identified in the results of the first four stages of analysis and Section 6.2 illustrated mathematics related episodes from players' gameplay which were selected and grouped in themes after the fifth and sixth stages of analysis.

The open codes and categories (Section 6.1.1) that were shaped during the first stage of analysis revealed that, during their gameplay, players were making comparisons of the cost and size of several virtual artefacts, were having issues dealing with empty areas and were arranging and structuring the house rooms and their furniture. In addition, in House 2 gameplay in particular, players were thinking of ways of saving on and increasing the budget of the family they had selected.

Furthermore, the results of the second and third stages of analysis (Section 6.1.2) suggested that players employed their mathematical prior understandings in order to initiate and mostly process the sub-goals they had set during their overall gameplay. The percentage of use of mathematical prior understandings increased noticeably in House 2 gameplay, indicating that in a more constrained gameplay (House 2 gameplay), players used their mathematical prior understandings more often than in a less constrained gameplay (House 1 gameplay). Moreover, the sub-goals in which the mathematical prior understanding (MU) code was coded and the open codes that occurred in the fifth stage of analysis indicated that in a less constrained gameplay (House 1 gameplay) players mostly employed mathematical prior understandings related to the *arrangement and/or placement* of the virtual artefacts in their houses (and in M&C group to the *size* of the virtual artefacts). In addition, in a more constrained gameplay (House 2 gameplay) players mostly employed mathematical prior understandings related to the comparison of the cost (value) of the items they would buy for the family and also related to players thinking of ways of saving on and/or increasing the budget of the family. This means that during House 2 gameplay, the budget of the family played a key role in the players' building process and the elements of mathematical prior understandings that players used during gameplay.

Furthermore, examining the sub-goals of all groups' gameplay, which were coded with mathematical prior understandings (MU) and also *Exploratory Talk* (EXPL) an observation was made. Both MU and EXPL codes' percentages were increased in House 2 gameplay in comparison to House 1 gameplay. Nonetheless, it appears that whilst processing most of the sub-goals for which the groups shared an *Exploratory* type of talk, players' actions required the use of mathematical prior understandings as well. However, in almost half of the sub-goals for which the groups used their mathematical prior understandings, players also shared an *Exploratory* type of talk. This, perhaps, indicates that most of the sub-goals where players were exploring critically each other's ideas and were reaching a final decision as a group (*Exploratory Talk*) involved players' mathematical prior understandings. Such sub-goals were selected in order to form the episodes that were presented in Section 6.2 of this chapter.

The selected episodes of interest of players' gameplay that were presented in detail in Section 6.2 illustrated common issues that players faced during their House 1 and House 2 gameplay that involved the use of their mathematical prior understandings and – in most episodes – their *Exploratory Talk*. In House 1 gameplay, some groups faced issues when dealing with their house's large size and proceeded with some, rather unorthodox, ways of 'filling in the empty space'. One group (M&C, House 1) had troubles in creating a curved shaped swimming pool for their house as they could not manipulate the slider variables of the menu successfully and another group (S&K, House 1) wanted to create the 'the same' two bedrooms in the first floor and this resulted in having them talking about elements of symmetry, but not using formal mathematics language.

In House 2 gameplay, all groups faced the same challenge: to build a house for a Sims family with a given budget. Thus, they all had to consider the available budget. However, only two groups managed to create the house without spending the entire budget of the family; A&E and S&K. Those two groups seemed careful when creating and furnishing the family's house as they were explicitly thinking of ways of saving on the family's budget (Section 6.2.2). For example, they aimed in creating a small house that would be furnished with cheap (sometimes the cheapest available) and 'necessary' items and in some cases they were also making cost-effective decisions regarding the way the house was structured and/or furnished. Those two groups were also concerned with their house's appearance and explored the menu options more. Therefore, they both discovered the 'Create a Style' option which enabled them to decorate their house's items for free and S&K also discovered the 'Eyedropper' option which enabled them to copy and paste a certain style on their floor tiles. As a result, those two groups managed to create a house that they eventually liked and without spending the entire family's budget.

Even though M&C and G&N groups also wanted to create a small house, they initially did not create a small house which resulted in spending the majority of the family's budget on the foundations and walls of the house. Eventually, those two groups reached to a point where they had spent the entire family's budget and most of the menu items became unavailable for buying. Thus, they had to think of ways of increasing the family's budget balance (Section 6.2.3). There were two ways that both of those groups used: i. Selling (deleting) furniture and other items that they had already bought and placed in the house and get a full refund and ii. Deleting parts of the house and get an almost full refund. M&C and G&N, in fact, deleted parts of the house several times during House 2 gameplay and restructured their house's rooms. They eventually finished the family's house, like S&K and A&E did, but they had to change their initial plan because of the budget constraint.

Lastly, even when all groups stated that they had finished the family's house in House 2 gameplay and played with their Sims family in the Live mode, they all had to make changes to their house as they got feedback from the reactions and the '*mood*' and '*need*' meters of their Sims family (Section 6.2.4). For example, players had to buy appliances for their Sims, such as an oven for their Sims to cook or a Hi-Fi system as items to increase their Sims mood. In fact A&E considered their Sims need to read and bought a library before playing the Live mode. In addition, all Sims family members were unhappy by the fact that their house did not have wallpapers but only M&C, A&E and S&K noticed that from the menu's Live mode display and made adjustments to their Sims house in order to make their Sims happy. After all, House 2 was built, furnished and decorated to suit the needs of that Sims family.

Part III: Discussion of findings and Conclusion

Chapter 7 – Discussion

This chapter aims to address the thesis' general and research questions and discuss findings that emerged from the analysis of this research's data in relation to the existing related literature. Following the results presented earlier in Chapter 4, Chapter 5 and Chapter 6, I first address the research questions of this thesis in Section 7.1. Then, in Sections 7.2, 7.3 and 7.4, I further discuss findings that emerged whilst addressing the research questions. In Section 7.2 I argue that the interplay of players' gameplay, players' interaction and prior understandings and the game's virtual artefacts and rules was a 'web' in the sense of Noss & Hoyles' (1996a, p. 108) idea of 'webbing'. In the same section, I also illustrate two examples from players' gameplay, discussing the way players appropriated game's virtual artefacts and used them as tools in their gameplay, discussing their instrumental genesis (Guin & Trouche, 1999) in gameplay. Next, in Section 7.3 I discuss the mathematics that arose in *The Sims 3* gameplay arguing that it was 'blended' and inseparable from the context of the gameplay and it was influenced by the task that was set to the groups, the game's virtual artefacts and rules and players' discourse whilst being engaged in their gameplay activity. This chapter ends with Section 7.4 which focuses on players' gameplay in an open-world, real life simulation sandbox game such as *The Sims 3* and a brief summary of this chapter in Section 7.5.

7.1 Addressing the research questions

In Chapter 1 (see Section 1.2, p.5), I set the following general question: *How does players' mathematical thinking emerge and/or is affected while being engaged in the collaborative activity of building virtual houses in The Sims 3 digital game, in out-of-school settings?*. In order to address the general question of this thesis, I set four research questions that guided my research design (see Section 1.2, p.5). This section of the Discussion chapter addresses those four research questions through a discussion of the related existing literature and the results that derived from this research. Because the research questions of this thesis and this Discussion chapter discusses mathematical thinking, I provide again the operational definition of mathematical thinking as perceived in this thesis (see Section 2.5, p.43): *Mathematical thinking is a cognitive/physical activity in which mathematical (i.e. arithmetic, algebraic, geometric, logical, etc.) relationships are explored, is prompted by a need (intrinsic/extrinsic) and is evidenced through mathematical actions (cognitive/physical).*

The subsections in this section address each research question. I first outline the potential for mathematical thinking in *The Sims 3* as a game in Section 7.1.1. Then I discuss the way mathematical thinking is influenced when players engage in a less constrained and in a constrained gameplay in Section 7.1.2. Next, I illustrate the way players interact with each other and collaborate during a less constrained and in a constrained gameplay in Section 7.1.3 and lastly, I describe the way players' goal-directed actions emerge during *The Sims 3* gameplay in Section 7.1.4. At the end of this section I summarise the findings in order to answer the general question of this thesis and discuss the way mathematical thinking emerged during gameplay in Section 7.1.5.

7.1.1 RQ1: What potential is there for mathematical thinking in *The Sims* 3 as a game?

The rationale for this research question was to explore the potential for enabling players' mathematical thinking in *The Sims 3* game pre-set digital artefacts and rules and restrictions which are applicable, generally, to any player who plays this particular digital game. Drawing on the results presented earlier in Chapters 4, 5 and 6 (reference to the exact results' section will be made when necessary) from the four groups' gameplay in order to support that there is potential for mathematical thinking in *The Sims 3* as a game[5]. In this section I argue that this potential lies in the game's open-ended nature as a real-life simulation sandbox game, in the game's virtual artefacts available in the game's menus and in the game's rules and restrictions in which the game's gameplay is built. The way such potential is realised

[5] It is acknowledged that there might be a greater potential for MT in *The Sims* 3 as a game than what is reported in this Discussion chapter. However, the elements reported in this thesis are based on the findings as derived from the data of this research.

in more and in less constrained gameplay will be discussed when addressing the second research question (Section 7.1.2).

7.1.1.1 *The Sims* 3 as a sandbox game

Earlier in this thesis (see Section 2.4.4.2, p.38), I described *The Sims 3* as a popular real life simulation digital game. A key characteristic of *The Sims 3* game is that it does not involve explicit conflicts and goals. Rather, this game is a sandbox game (Juul, 2003); it provides a digital environment where players can set their own goals during gameplay and can edit the on screen environment. However, players are constrained by the fact that the game is digitally created software. As a digital virtual world, it involves digital artefacts and, as a game, it has game mechanics (Gee, 2007) and comes with rules and restrictions that are designed by its creators (Crawford, 2003). The game in this case (and, likewise, much computer-mediated software) is a key player in the *'distribution of agency'* (Gresalfi et al., 2008, p. 53). Thus, even though players can set their own goals in *The Sims 3*, their decisions and, therefore, gameplay is affected and bounded by what is available in the digital world of the game and also by what is allowed by the game's rules and restrictions (Bogost, 2007). From this point onwards, I refer to these bounded decisions as '*b-decisions*'.

As illustrated in Chapters 4, 5 and 6, in order to create the virtual houses in *The Sims 3* game all groups in this research went through a series of goal-directed actions whilst editing the onscreen environment of the game which involved: i. *building* the house (creating the foundations of the house and creating walls to shape the house and the rooms), ii. *furnishing* the house and iii. *decorating* the house. Apart from creating the foundations which was an action performed first in all groups, the other two series of actions were not necessarily performed in that order by the groups. This is because *The Sims 3* game is a sandbox game (Juul, 2003) that allows players to edit the onscreen environment in an open way and this was important for this research as it allowed players to explore the (mathematical) relationships within the context of the game as they proceeded with their gameplay, manipulating the game's virtual artefacts and interacting with the game's rules and constraints.

7.1.1.2 The game's virtual artefacts in the game's menus

The results of this research provide evidence that, overall, in order to achieve the majority of their goals players used the game's virtual artefacts (GVAs). Indeed, each one of the series of goal-directed actions described above (building, furnishing and decorating) require players to use GVAs, which are organised in the game's Build and Buy mode menus. Each GVA's appearance and properties (i.e. size, height, width, cost, colour), as well as the kind of information that pops up when players interact with the game's content, are created by the game's designers. However, due to the sandbox nature of this game (Clark, Nelson, Sengupta & D'Angelo, 2009), players can make changes to the GVA's appearance (chromatic changes mostly) using the 'Create a Style' or the 'Eyedropper' customisation options (see Chapter 6, Section 6.2.2.5, p.181), which, as it will be discussed in Section 7.1.2, was used by two of the groups during their gameplay in order to save on the family's budget.

As shown in the four groups' gameplay, any GVA that players add in the plot area in order to shape their virtual house is placed as a 3D object and the minimum space area that a GVA can take is of one 'square-tile'. All GVAs in the Build and Buy mode menus are displayed in a static 3D format and once players click on them, they automatically rotate and slightly enlarge in order for players to have a closer look. All GVAs have predefined dimensions but the actual size of a GVA is realised once it is selected by the player from the menu and is moved onto the building terrain (See M&C episode in Section 6.2.1.1, p.167). In addition, there are no measurement instruments (i.e. rulers) showing the exact size of the house the players are creating, apart from a grid that separates the area in square-tiles (see Figure 4-5, in p.95). However all groups in this research enabled the grid in order to be able to view the terrain they were working on in square-tiles. The absence of clear measurement instruments to assist players placing GVAs in their house, enabled them to estimate sizes and costs by using other GVAs and in some cases their own created virtual artefacts (PVAs) during their gameplay.

Furthermore, the content of the game's menu and the game's virtual artefacts change when players are playing with a Sims family in the Live mode of the game. All groups in this research played the Live mode when they were asked to create their second house for a virtual family from the game's inventory. The Live mode menu displays information regarding the motives or desires of the family members of the household's family and meters that show the status of the mood and needs of the specific Sims virtual character that players manipulate. *The Sims*' mood meter appears as a bar that can change from low to high depending on the overall status of *The Sims*' needs' meters, cognitive and physical, that are present in the Live mode content display (see Chapter 6, Figure 6-6, p.191). There is a pre-existing relationship between the needs meters and the overall mood meter that was designed by the game's creators and depending on the needs players attend to (or not), *The Sims* overall mood changes accordingly.. It is up to the player to attend (or not) to those needs and subsequently to maintain a high level mood meter (happy) or not, whilst controlling the actions of their Sims virtual characters. Overall, in all groups, players set major goals and sub-goals which emerged because of the content of the Live mode menu and their interaction with it. Even though the game's menus allow players to make b-decisions as described above, *The Sims 3* is a game and as a game, it is built upon rules and restrictions that influence players' gameplay.

7.1.1.3 The game's rules and restrictions

In *The Sims 3* game gameplay there are certain rules and restrictions that apply in the processes of building, furnishing and decorating virtual houses in the game. There are restrictions derived from certain properties of the GVAs, such as their size, height and cost and there are rules that govern the manipulation of those GVAs and their placement from the game's menu to the – under construction – house. In terms of placing and arranging GVAs in a virtual house, there is a 'free', yet restricted way in which players can place and arrange GVAs in this game and as Gee and Hayes (2010, p.114) state, in *The Sims*' Build mode, there are "tools [that] require one to use a good deal of geometry to get all the angles and shapes to fit perfectly together". Players cannot place GVAs (i.e. furniture, doors, windows) that exceed the overall height or width of the area they intended to place and players must place GVAs in ways that allow for enough space for *The Sims* to move around in the house (Electronic Arts, 2010). In addition, players cannot place foundations or other GVAs within two 'square-tiles' of the plot's boundaries or pavement, which is something that derives from real-life urban planning practice. All players in this research encountered such restrictions during their gameplay and when such incidences emerged, the game communicated that to players either by changing the surrounding colour of the GVA from green to red and/or by presenting a pop up phrase – message that provided players with explanation of the specific restriction. Such incidences were coded in Chapter 5 (Section 5.3.1.1, p.140)as Game Restrictions (GR).

An important integrated feature of the game with respect to mathematics and gameplay, is that it has a currency system in which everything the players add (or delete) in their gameplay has a pre-defined cost-value. Depending on whether there is a Sims family involved in the gameplay or not also affects the rules and restrictions because there is a budget constraint enabled and therefore, additional restrictions. If a family is involved in the gameplay like in House 2 gameplay, then a family's budget balance meter indicates the status of the budget. When players are buying furniture and other items for *The Sims* family from the existing menu in the Buy mode, it involves transactions that feature Simoleons (the currency of the game). When players buy or delete an item then the balance decreases or increases the family's budget balance respectively. The game's rules do not allow players to exceed that budget balance amount whilst building and/or buying items for that specific family. If a family cannot afford buying a specific house or plot (the family's budget balance is lower than the value of the house or plot) then the game (rules) does not allow players buying that house or plot. If a family's budget balance is reduced in a way that the family cannot afford buying items from the menus then all items the cost of which exceeds the budget balance are marked with a red colour and players cannot buy those items until the budget balance is sufficient. This was something that affected the way some of the groups used mathematics in their gameplay (see M&C and G&N episodes in Chapter 6, Section 6.2.3, p.185) whilst building the second house and will be discussed in more detail in Section 7.1.2.

To summarise, when creating a virtual house in *The Sims 3*, from scratch, players use the mouse (and keyboard) to select, drag and drop, add, delete and manipulate GVAs into an empty plot area that has a grid layer that divides the plot (and house area) in 'square-tile' units. In order to create the exterior and interior structure of the house, furnish and decorate the house and the rooms, players need to select, place and arrange 3D objects – GVAs, such as walls, foundations, tiles, furniture, appliances and decorative items, in the plot area or in the house area but they are constrained by the *The Sims 3* game designers' 'procedural rhetoric' (Bogost, 2007, p.ix); by what is available in the game's Build and Buy mode menus and also by what is allowed by the game's rules and restrictions (Salen & Zimmerman, 2003). In addition, when players play the Live mode of the game, which involves a family and a family's budget, players need to understand the currency and the rules of the buy-sell processes of the game.

Thus, the potential for mathematical thinking in *The Sims 3* as a game lies in the mathematical relationships that are buried in the digital artefacts, rules and restrictions of *The Sims 3* game that are designed and created by the game's creators. During gameplay, players interact with these digital artefacts, rules and restrictions and as shown by the results in Chapters 4, 5 and 6 players' gameplay was less constrained in House 1 gameplay and more constrained in House 2 gameplay, because a Sims family was involved and this influenced mathematical thinking, as it will be discussed next.

7.1.2 RQ2: How does players' mathematical thinking emerge and how is it influenced when players engage in a less constrained and in a constrained gameplay?

The rationale behind this research question emerged from the task design of this research; players were asked to build two virtual houses: House 1 without a Sims family being involved using the Build and Buy mode and House 2 for a Sims family they would select from the game's menu using the Build, the Buy and the Live modes. As discussed in the previous section, players' gameplay in *The Sims 3* is constrained by what is available in the game's menus and by the game's rules and restrictions but when a Sims family is involved, players' gameplay is more constrained by the family's budget, need and mood meters that are enabled in Live mode. This section discusses the way players' mathematics-related actions and mathematical thinking were influenced as a result of those constraints that emerged during House 2 gameplay. In doing so, I start by recapping results related to this research question from Chapters 5 and 6: Section 5.3.1 (p.140), Section 6.1.1 (p.157), Section 6.1.2.1 (p.159) and gameplay episodes from Sections 6.2.1, 6.2.2

and 6.2.3 (pp.167-190). This leads to a discussion on players' mathematical prior understandings' use in less and more constrained gameplay and players' ways of dealing with the constraints, in particular the budget constraint, so as to accomplish their task in a desirable way.

Ovearll, whilst being engaged in less constrained gameplay (House 1 gameplay) all groups explored the content of the game's menus and the game's rules for the first time. As illustrated by the sequence of their sub-goals and actions, in House 1 gameplay, all groups would drag and drop, delete and rearrange the position of GVAs several times in order to achieve a desirable outcome. In addition, they all explored the options available in the game's menu and selected furniture and other GVAs from the menus mainly based on their appearance and whether they liked them in their virtual house, regardless of their price (see Section 5.1.3, p.130). The lack of budget constraints influenced the size and appearance of the groups' 1st house. As shown earlier (see Chapter 4, p. 89), in a less constrained gameplay, all groups created a large (except for A&E who created a relatively small) and luxurious house which in some cases (M&C and G&N, see Section 6.2.1.1, p.167) there were exaggerations made to *"fill the empty space"* of the quite large rooms. Nonetheless, players' decisions regarding the selection of expensive and luxurious items for their houses is often reported in *The Sims* gameplay, as Montes and Cambell (2013) criticise the game's mechanics for promoting virtual consumerism. However, this was not the case when players were engaged in a (more) constrained gameplay, during House 2 gameplay. The budget constraint influenced the final size and structure of all groups' 2nd house as well as the groups' selections for furniture and decorations. That was because, during House 2 gameplay, all groups created smaller houses, in comparison to House 1 gameplay and were explicitly selecting relatively cheap furniture and other GVAs in order to furnish and decorate their houses, driven by the family's budget and needs.

Overall, the budget constraint influenced the prior mathematical understandings that players used whilst building the family's virtual house in House 2 gameplay. In order to support this, I recall the results of the open code analysis of the mathematical prior understandings codes that were presented earlier in Table 6-1 (p.159). In House 1 gameplay players' prior mathematical understandings were mostly used when players had issues with the size of their houses and the arrangement of the GVAs. Even though the price of the GVAs was displayed when players were clicking on the GVAs in the Build and Buy mode menus, both in House 1 and in House 2 gameplay, none of the groups talked about the cost of the GVAs and the budget of the family in House 1 gameplay, as there was not a family involved. However, in House 2 gameplay, the constraints and rules that players encountered "provide[d] stiumulus to begin thinking" (Burton, 1984, p.36) as players were talking about the cost of the GVAs and the available budget of the family, they were comparing the GVAs' prices in order to select a cheap option and they were thinking of ways for saving on the budget. Specifically, during House 2 gameplay, players' b-decisions were influenced by the fact that every time they were adding something in *The Sims* family's house there was an amount with a minus symbol (i.e. -§50) being displayed by the game as soon as the GVA was added and the budget of the family was being reduced accordingly.

The budget constraint was a challenge for players, set by the game's rules and the game's designers (Crawford, 2003; Suits, 2005). In particular, the moments where players were challenged by the game's content and rules, such as the moments that they had spent almost almost the entire family's budget and all items were displayed red because the family could not afford buying them, were "breakdown moments[6]" for those players. In such moments, players' goal-directed actions that were "ordinarily [be] characterised as unproblematic, routine actions…" (Noss, Hoyles and Pozzi 1998, p.108), such as players' initial pattern of b-decisions of buying the necessary and cheapest available options throughout House 2 gameplay, *"were replaced by conflict, disagreement and doubt, resulting in more spontaneous explanations"*(ibid) because players' goals were challenged, were in 'conflict' with the game's rules as designed by its creators (Crawford, 2003; Salen & Zimmerman, 2003) and the budget constraint was affecting their gameplay as they could no longer proceed with their once routine actions of buying items to finish House 2.

Overall, in such situations, players went through a process that was similar to Polya's (1945) four phases of problem –solving and Mason, Burton and Stacey's

[6] Perhaps in a weaker sense than the one proposed by Noss, Hoyles and Pozzi (1998, p.108)

(1985, p.26) three phases of "tackling a question"; they first made sense of the issue, then interacted with each other negotiating their next steps, made a plan to resolve the issue and once they carried out their plan, they assessed whether the outcome was acceptable or whether they should revise their plan accordingly. Nonetheless, as it will be discussed in more detail in Section 7.1.4 (p.219), the way players worked through such issues was complex and did not necessarily follow a structured route.

Therefore, the budget constraint in House 2 gameplay resulted in getting the groups to think of ways for saving on the budget. As illustrated in the results of Chapter 6 (see Section 6.2.2, p.173), there were three ways that all groups followed in order to save on the budget. First, all groups explicitly stated that they would create a smaller-sized house in comparison to their 1st house. This means that all groups realised that the size of their houses affected the house's cost. Second, all groups selected, mostly, the cheapest available options when furnishing and decorating House 2. They were exploring the game's Buy menu, comparing prices in order to select cheap furniture, wallpapers and floor tiles. In fact, in House 2 gameplay, all groups were selecting the cheapest – and some groups (A&E and S&K) the §0 cost – GVAs from the menu. Thus, the groups realised that the overall value of the furniture affected the house's cost as well. Third, all groups created only what they thought was necessary for a family and only selected furniture that the family would need to live in that house. This was also evident when comparing the number and content of the rooms in House 1 and in House 2. This means that the groups realised that the number of the GVAs also affected the house's cost but there were some GVAs that were necessary for the house's functionality and virtual family's needs. The latter will be discussed in more detail in Section 7.2.

Despite their effort on creating a small(er) house and selecting only necessary and cheap GVAs to furnish and decorate their family's house, two of the groups (M&C and G&N) spent almost the entire amount of the family's budget before completing the family's house. As a result, these groups had to think of ways to increase the budget because the game's rules did not allow players to buy items the value of which was higher than the available balance. There were two ways in which those groups managed to increase the budget and finish the family's house; i. selling GVAs that they had already placed in the house, such as furniture and lamps, receiving this way full refund and ii. deleting parts of the house, such as foundations and walls, receiving this way a partial refund. The second way, however, resulted in reshaping parts of the house, which caused players rethinking the size and structure of the walls, foundations and rooms of the house.

Nonetheless, the two groups who successfully managed to finish the houses without spending the entire family's budget (A&E and S&K) finished the house leaving the family with almost 25% of their initial budget balance. But why these two groups managed to create the houses without spending the entire budget? Apart from the three ways of saving on the budget, that were evident in all groups' House 2 gameplay, A&E and S&K made some cost-effective b-decisions when shaping the interior structure of the house so as to save money, such asnot having corridors and spent less on walls,deleting parts of the walls in some rooms to make entrance points instead of buying doors and so on (see Section 6.2.2.4 and 6.2.2.5, pp.178-181). In addition, those two groups saved a lot on the budget because they used the 'Create a Style' (A&E) and 'Eyedropper' (S&K) options of the game in order to customise the appearance (colours) of the wallpapers and floor tiles respectively without spending money. The appearance of their virtual houses was important for most of the groups (M&C, A&E and S&K) and they wanted their 2nd house to look nice but were not satisfied with the appearance of the §0 cost wallpapers and tiles that were available in the game's menu. A&E recalled the 'Create a Style' customisation option that they had discovered and used in House 1 gameplay in order to customise in a desirable way the previously placed §0-cost wallpapers of their house, without spending any money. Similarly, S&K discovered the 'Eyedropper' customisation option during House 2 gameplay and painted their previously selected §0-cost floor tiles in a desirable pattern. M&C did not explore the entire menu of the game and did not discover those two options, neither the §0 cost options for wallpapers and tiles but there is not sufficient evidence from the data to explain why they did not do so. Perhaps they did not expect the game to provide §0 cost options and did not explore the menus further or they were satisfied with the cost of the items they had viewed in the game's menu. As a result, they spent a lot of money on the wallpapers and floor tiles because one of the most expensive parts in the building process in *The Sims 3* game, apart from the foundations and walls, is the addition of floor tiles and wallpapers. The way A&E and S&K used the two options of the game as tools to save on the family's budget will be discussed in more detail in Section 7.2.

Returning to Section 7.1.1, I concluded that the potential for mathematical thinking in *The Sims 3* as a game lies in the mathematical relationships that are buried in the game's artefacts, rules and restrictions. The budget constraint is enabled as part of the game's rules when players select to play with a family in the Live mode. This section showed that this constraint influenced the way players used the game's artefacts and their prior mathematical understandings to solve problematic situations that emerged as a result of that budget constraint. In such problematic situations, the mathematical relationships became 'mobilised' in gameplay through players' goal-directed actions during gameplay. This *"mobilisation-in-use"* (Noss & Hoyles, 1996a, p.34) of the mathematics during gameplay will be discussed in more detail in Section 7.3. Yet, apart from interacting with the game's content and rules, players also interacted with each other in this research, forming their goals during their gameplay. Next, I will illustrate the way players' interacted with each other and collaborated in less constrained and constrained gameplay, so as to address the third research question of this thesis.

7.1.3 RQ3: How do players collaborate during a less constrained and during a constrained gameplay?

This research question was initially formed because players were asked to play this game in groups of two, using one laptop (one keyboard and one mouse), as part of this research's design. *The Sims 3* game is a single player game title (Electronic Arts, 2010) but in this research, players participated as a group in order to create the two virtual houses, because I expected players to work together, interact and talk, sharing their thoughts and goals to each other during their gameplay, making them explicit to me during data collection. In order to address this research question in this section, I first briefly revisit literature related to collaboration and then recapitulate results related to the analysis of players' talk in the fourth stage of analysis, in respect to the two houses' gameplay (see Section 5.3.2, p.147 and Table 5-6, p.139). This leads to a discussion on the way players' interaction with each other and their talk (influenced and) were influenced by and also influenced the two tasks of creating virtual houses in less constrained and constrained gameplay.

Earlier, in Chapter 3 (see Section 3.2.2.1, p.54), I referred to cooperation and collaboration as ways of interacting for accomplishing a task as a group. Members of a group cooperate when they divide the common task in subtasks and take responsibility for individual parts (Dillenbourg, Baker, Blaye & O'Malley, 1996) and they collaborate when they share ideas and jointly construct knowledge whilst working together on the task (Hämäläinen et al., 2011). Overall, in this research, all groups managed to create the two virtual houses in a way that satisfied them. However, reviewing each group's gameplay audio-visual data and the results of all stages of analysis earlier in Chapter 5 (see Section 5.3.2, p. 147), most of the time players worked in collaboration but there were times, especially in House 1 gameplay, where some groups worked in cooperation. The groups' collaboration was influenced by the processes the groups followed in order to accomplish their task (Hämäläinen, 2008) and by the fact that House 1 was created during a less constrained gameplay whereas House 2 was created during a constrained gameplay, for a specific family with a budget constraint.

The task of creating a virtual house during House 1 gameplay was interpreted differently by the groups. The house that M&C, G&N and S&K groups created in House 1 gameplay was perceived by those groups as their 'own' virtual house and therefore were building, furnishing and decorating the house following their own preferences, whereas A&E created House 1 explicitly stating that it was meant for someone else and perhaps this influenced the way they worked together in order to create it. In particular, all groups created the shared rooms of House 1, such as the kitchen and living room, in collaboration but the groups who created their 'own' bedrooms separately (M&C and G&N), worked in cooperation because they had different preferences. In fact, as indicated by the results of the fourth stage of analysis (see Chapter 5, Table 5-6, p.139), there were times during House 1 gameplay where they did not even talk to each other or were talking alone (monologues) because each one was creating the bedroom individually. Even though S&K created their 'own' house as well, they created all rooms of House 1, even their bedroom, as shared rooms and both S&K shared responsibility for the whole House 1, similarly to A&E in House 1 gameplay.

Furthermore, players' collaboration unfolded during gameplay and became 'visible' through their talk whilst they were forming goals and performing actions. The analysis of players' type of talk (fourth stage of analysis, see Chapter 5, Table 5-6) in both House 1 and House 2 gameplay showed that in the majority of the sub-goals that players processed during their gameplay, their talk was coded as *Cumulative*. This suggests that during the majority of both House 1 and House 2 gameplay, players were positively, yet uncritically, building on each other's ideas (Mercer, 2010). Nonetheless, as discussed earlier in Chapter 5 (see Section 5.4, p.152) the analysis of players' type of talk provided evidence that players' talk that was coded as *Exploratory* increased in House 2 gameplay, in comparison to the percentages of the *Exploratory Talk* coded in House 1 gameplay. At the same time, players' talk that was coded as *Disputational*, *None* or *Monologue* in House 1 gameplay, decreased a lot in House 2 gameplay. This suggests that when players were engaged in a constrained gameplay, such as in House 2 gameplay, they were explaining and justifying their suggestions to each other more often than in the less constrained House 1 gameplay and shared less incidences of individual work. Perhaps the constraints they encountered in House 2 gameplay, which were more related to the budget and its restrictions, required players to become more cautious and engage in a talk in which they would explore their options before proceeding with their actions.

More specifically, *The Sims* family that was involved and the budget constraint that was enabled in House 2 gameplay influenced players' collaboration because the groups had a more specific common object: to create a virtual house for a family with certain needs, within a specific budget allowance. Therefore, players explicitly shared and negotiated their ideas in order to save on the family's budget (see Section 6.2.2, p.173) and, in M&C and G&N groups' case, in order to increase the budget's balance when the game restricted their buying options (see Section 6.2.3, p.185). In addition, as indicated by the results of the first stage of analysis (see Table 5-3, p. 130 in Chapter 5), players' emotions[7] when referring to the budget and

[7] The term 'emotion' was used during the first stage of analysis as one of the codes characterising players' gameplay. However, players' emotions were not analysed further in terms of affect research analysis.

budget issues were more frequently coded in House 2 gameplay, suggesting that, overall, players became more attached to the constrained gameplay. In such constrained gameplay, players were challenged and were set in situations where “breakdown moments” occurred and important decisions had to be made. Thus, players had to renegotiate their initial gameplay strategy and share *“spontaneous explanations”* (Pozzi, Noss & Hoyles, 1998, p.108) which were explicitly stated through their talk and in particular through their use of *Exploratory Talk* in such situations during their gameplay (see for example A&E talk in Section 6.2.2.5, p.181). Nonetheless, players managed to successfully overcome the challenges because their own skills and the challenge of the task were high and in balance and because, despite the fact they were being challenged, the tasks were under their control (Schernoff, Csikszentmihalyi, Schneider & Shernoff, 2003, Bourgonjon et al., 2010; Sandford, Ulicsak, Facer & Rudd, 2006).

7.1.4 RQ4: How do players’ goal-directed actions emerge during *The Sims* 3 gameplay?

The rationale for this research question was to explore the way players’ gameplay unfolded and because, as discussed earlier in Section 7.1.1.1, *The Sims 3* game is a sandbox game that allows players to set their own goals, I specifically wanted to explore the way players’ goals, that directed their actions, emerged during gameplay. In order to do so, I recap results relevant to this research question from Chapters 5 and 6: Section 5.2 (p.131); Section 5.3 (p. 135); Section 5.3.1 (p.140) and Section 5.4, p.152. This leads to a discussion on gameplay complexity and the place of emergent goals (Saxe, 1991) in players’ interaction, prior understandings and gameplay.

Recall that the objects of the two activities that players in this research were engaged in were shared to the four groups by the researcher; Activity 1 was to create House 1 without a Sims family being involved and Activity 2 was to create House 2 for a Sims family. Even though each group managed to create the two houses in a way that satisfied them, the emergence of the goal-directed actions, the sequence of actions that constituted those two activities and the tools that each group used during their gameplay were influenced by several parameters and were not the same for all groups. The diversity of gameplay in open-world and sandbox game environments was previously reported in research (Tornqvist, 2015; Avraamidou et al., 2012; Squire, 2008; Gee, 2014). In this study, the results of the second stage of analysis that were presented earlier in Chapter 5 (see Section 5.3, p. 135) revealed that the players' activity was goal-directed activity (Leont'ev, 1981) and the goals that directed the actions of each group were indeed formed in a complicated way during gameplay; players' goal-directed actions were not performed in a linear process, rather, many of the players' goal-directed actions were connected to each other in a nested way.

In particular, players were setting goals and whilst acting in order to achieve those goals, other goals emerged as 'things needed to be done' in order to proceed with gameplay. There were major goals which were goals that were explicitly set by players and directed their actions, similarly to Leont'ev (1981) activity-goal-operations hierearchy and there were sub-goals which were 'must do' things that also directed players' actions but emerged during gameplayinSaxe's (1991) emergent goals' senseand served as *'means to ends'* to a previously set *'major'* goal.

The results of the second stage of analysis (see Chapter 5, Section 5.2, p.131), showed that players' set more major goals and sub-goals in House 1 gameplay, in comparison to House 2 gameplay. Nonetheless, it was observed (see Chapter 5, Table 5-4, p.132) that even though the numbers in House 2 gameplay decreased, the ratio of the major goals to the sub-goals in House 2 gameplay increased in all groups, in comparison to the respective ratio in House 1 gameplay. This suggests that the groups' goal-directed actions in House 2 gameplay were more specific and focused in terms of what the players wanted to do and, perhaps, due to the familiarisation that players had with the game's content and rules in House 1 gameplay, there were less things 'needed to be done' in House 2 gameplay. The episode from S&K's gameplay that was presented earlier in Chapter 6 (see Section 6.2.5.2, p.196) is an example of a complicated major goal which required players to perform a number of goal-directed actions, forming a respective number of sub-goals during gameplay.

Nevertheless, not all major goals and sub-goals were achieved by players. There were some sub-goals, mostly in House 1 gameplay, that players had formed but were paused and/or abandoned during gameplay. The majority of the abandoned sub-goals were not pursued by players because players could not overcome challenges that emerged because of the game's rules and restrictions (see Section 5.3.1.1, p.140). Nonetheless, there were some sub-goals that players temporarily stopped processing for a brief time but then returned to a few moments 'later' during their gameplay in order to accomplish them (see Chapter 5, Section 5.2, p.131). Players' capability of forming, pausing, returning to or abandoning their sub-goals whilst playing this sandbox game shows that, despite the challenges that were emerging during gameplay and the fact that the task was set by the researcher, it appears that, during gameplay, the tasks were 'appropriated' (in the sense used by Wertsch, 1991) as their own and they were under players' control (Schernoff, Csikszentmihalyi, Schneider & Shernoff, 2003).

Nonetheless, the way players' goals emerged was influenced by several parameters. As discussed earlier in Chapter 5 (see Section 5.3.1, p.140) the results of the third and fourth stages of analysis revealed that the majority of the sub-goals' formation was influenced by: i. the players' interaction with each other because most of the sub-goals in both House 1 and House 2 gameplay were initiated by the players through their talk, ii. the game's and players virtual artefacts that were used by players and the rules of the game that players' encountered during their gameplay and iii. the players' use of their prior understandings and, in particular, their everyday prior understandings because their task was to create, furnish and decorate virtual houses with/without a virtual family. As it was concluded in Chapter 5 (see Section 5.4, p.152), players' interaction, players' prior understandings and the game's content were three elements that characterised most of the groups' gameplay. The interplay of *players – prior understandings – artefacts – gameplay* will be discussed in more detail in Section 7.2.

7.1.5 Addressing the general question of this thesis – How mathematical thinking emerged in *The Sims* 3 gameplay

In answering the general question of this thesis: The mathematical thinking that emerges in *The Sims 3* gameplay lies in the mathematical relationships in *The Sims 3* game, that are buried in the digital artefacts and rules of the game and become mobilised in gameplay through players' gameplay of *The Sims 3* game. Mathematical thinking emerged in situations where there was a need to explore mathematical relationships, such as numerical, arithmetic and geometric within the context of gameplay. Such situations required players to employ their mathematical prior understandings in order to perform mathematical actions such as comparing numbers, sizes and areas and arranging 3D objects in the virtual environment of the game so as to build their virtual houses driven by their goals. However, the mathematics that players used were not 'privileged' (Wertsch, 1991) in mathematics that can be found in school textbooks and curriculums and it was different than the mathematics used in a formal classroom (Avraamidou, Monaghan & Walker, 2015).

Reviewing the results of this research, mathematical thinking not only emerged and was used by players during *The Sims* 3 gameplay, but there is evidence to support that it was shaped and influenced by players' goals which were formed and influenced by the interplay of the players' prior understandings (mathematical and everyday), the game's digital artefacts and rules and the players' interaction with each other. This interplay echoes Saxe's (1991) emergent goal parameters which were identified during children's activity of selling candies in the streets of Brazil: prior understandings, conventions and artefacts, social interaction and activity structure.

Furthermore, mathematical thinking was most explicitly revealed when players were faced with unexpected situations of "breakdown moments" (Pozzi, Noss & Hoyles, 1998, p.108) during their gameplay. Such situations arose mainly as a result of tensions between players' goals and the game's rules and constraints as designed by its developers, sometimes leading to the emergence of additional goals that players needed to pursue. Therefore, mathematical thinking was employed in situations where players were challenged (Suits, 1978; Crawford, 2003) and needed to manipulate the game's virtual artefacts, using their mathematical and everyday prior understandings, talking to each other and collaborating in order to negotiate and eventually 'agree' on a solution to such unexpected situations so as to be able to proceed with their gameplay.

Moreover, in such incidences, players' interaction with each other through their talk acted as a medium that emabled and assisted players to make sense of the situation and communicate each others' thinking (Mercer, 2010). Players' talk became more *Exploratory* in the sense that players were explicitly sharing and justifying their opinions and ideas in order to reach a joint decision as a group. However, the decisions that players made during their gameplay were *'b-decisions'* as they were not necessarily 'free' decisions as such decisions were bounded to the context of the game, the game's digital artefacts and the game's rules and restrictions. As it will be discussed in more detail in Sections 7.2 and 7.3 that follow, as players' gameplay became more constrained, several situations emerged requiring players to set goals (Saxe, 1991) in which players had to negotiate decisions. This negotiation was realised through an interaction that, for most groups, was characterized with instances of exploratory talk (Mercer, 2010), mathematical thinking became more visible (Pozzi, Noss & Hoyles, 1998) as it was in such situations that players needed to use mathematical thinking to proceed with their gameplay.

7.2 Interplay of players' gameplay, prior understandings and the game's virtual artefacts and rules

As stated in Sections 7.1.4 and 7.1.5 above and in Chapter 5 (see Section 5.3, p.135), the formation and processing of players' goals which directed their actions during gameplay were mostly characterized and influenced by an interplay of: i. the game's virtual artefacts, rules and restrictions that players interacted with during gameplay, ii. the everyday and mathematical prior understandings that players brought into their gameplay activity, and iii. the players' interaction with each other. In this section I explore this further by recapping results from Chapter 6 (the specific references are made in the text that follows) related to players' use of their prior understandings as they were using the game's virtual artefacts and interacting with each other. I start (Section 7.2.1) with a discussion on the use of the aforementioned parameters as resources and I then focus on two specific game's virtual artefacts; the family's budget (Section 7.2.1.1) and the Live mode's meters (Section 7.2.1.2). Then in Section 7.2.2 I illustrate and discuss the way two of the groups appropriated the game's virtual artefacts and used them as tools to achieve their goals during their gameplay. This leads to a discussion on resources and tools and I argue that the interplay outlined above was inextricably linked to the context of that particular gameplay activity, acting as a dynamic resource (Hill & Hannafin, 2001) for the players; a system that both supported and bounded players' mathematical activity and mathematical thinking during gameplay.

7.2.1 An interplay of players' prior understandings, game's virtual artefacts and players' gameplay

Players in this research used the available resources and tools at hand in order to proceed with their gameplay. Such available resources and tools during their gameplay included a laptop, a digital game (content and rules employed during gameplay), players themselves and their prior understandings (everyday and mathematical) and the researcher. Players used the laptop only as a tool to play the game (and point to specific items on the screen during gameplay) and the researcher acted as a resource when introducing the game and when players were having technical difficulties, such as saving the game and so on. The digital game (content and rules employed during gameplay) and players themselves (interaction and prior understandings) as resources, were dynamic resources in the sense of the definition provided by Hill and Hannafin (2001, p.42) who referred to dynamic resources as resources that "…undergo frequent, sometimes continual, change". Indeed, as players' gameplay unfolded, players' understandings and gameplay experience were enhanced with new knowledge in a dynamic way, whilst they were exploring and interacting with the game's menu and rules and were shaping the onscreen environment, interacting with the game's geography (Egenfeldt-Nielsen et al., 2008), creating and editing their virtual houses.

All players' sub-goals were processed with actions that involved the game's and/or players' virtual artefacts (GVA and/or PVA) both in House 1 and in House 2 gameplay. When browsing the game's Build and Buy mode menus in order to select GVAs that they would place in their house, players interacted with the way *The Sims 3* designers created and organised the content of the game's menus and could only select items that were available in the menus. Nonetheless, the content and organisation of the game's Build and Buy mode menus acted as a resource for players.Whilst browsing the Buy mode's menu , players could see additional related GVAs that the game's designers created and classified in that specific submenu and this resulted in the emergence of new sub-goals for some players (see episode in Section 6.2.5.2, in p. 196). In addition,when clicking on a menu item, players could view information regarding the item's cost and could select pre-set appearance options. In House 2 gameplay, in particular, the cost information displayed in respect to each digital artefact in the Build and Buy mode menus, was important for players' gameplay because the groups had to create the house within the limits of the family's budget. Nevertheless, in House 1 gameplay, even though the cost was displayed, players did not explicitly talk about the cost of the items they were buying from the game's menu. This suggests that the content and the information displayed by the game's menu was a resource that was used by players when needed. This sandbox game's menu was a resource designed to allow players to: "take what is supportive from the ambient pedagogical setting, rather than 'receiving' what is given" (Noss & Hoyles, 1996a, p. 109).

However, whilst selecting most of the GVAs from the menus and placing them in their virtual houses, players used their everyday and/or mathematical prior understandings as well, as evident by the results presented earlier in Chapter 5 (see Section 5.3.1.2, p.144). Players mostly used their everyday prior understandings (EU) in order to form and process goals related to the way a real-life house is structured, furnished and decorated so as to be functional. Each group, at some point during their gameplay, explicitly mentioned their own houses, an acquaintance's or a real-life house as references (see Chapter 5, Table 5-2, p.128). Nonetheless, in order to reach a b-decision, especially in House 2 gameplay, players considered the budget and the cost of those EU references (GVAs) before selecting them for their house. For example, an episode from M&C's gameplay that was illustrated in Chapter 6 (see Section 6.2.2.2, in p.174), is an example of the way players used their everyday (EU) and mathematical (MU) prior understandings in order to select a cost-effective and at the same time, appropriate type of tile from the game's menu (GVA) for their bathroom's floor in House 2 gameplay.

The above interplay of GVA, EU and MU was often observed in players' gameplay, especially in processing sub-goals where players used their MU. As was illustrated earlier (see Chapter 6, Section 6.1.2.2, in p.161), in most of the goal-directed actions performed in House 2 gameplay and in which players used their MU, players also used their EU and the GVAs. In fact there was not a sub-goal in House 1 or House 2 gameplay that was coded as being processed by actions where players only used their MU. Rather, MU was used in combination to at least one other element and this was either GVA, PVA or the game's rules (GR). This provides evidence suggesting that the MU that players brought into gameplay acted as a resource for achieving their sub-goals but their MU, as a resource, worked together with – and was linked – to the context of the particular game, their EU and the game's content and rules. I will return to this in Section 7.3 that follows, but now, I shift my focus to the family's budget in order to discuss its use as a dynamic resource during gameplay.

7.2.1.1 The family's budget: a dynamic resource

The family's budget is an integral GVA of *The Sims 3* game that was enabled in House 2 gameplay only. As discussed earlier in this chapter (Sections 7.1.2 and 7.1.3) it influenced players' mathematical thinking and collaboration, because House 2 gameplay was constrained by the presence of a family that had a specific budget to spend. During gameplay, this GVA was mobilised and a dynamic resource in the sense that it would display information regarding the available Simoleons that the family could spend but for the players in this research in House 2 gameplay, it was also a restriction. This GVA was a means by which the game's designers communicated the rules and restrictions of the game regarding the buy-sell processes when a family is involved in the game. It was a dynamic resource for the players because the budget indicator's value was changing in respect to whether players were buying or selling (deleting) items during their gameplay and when this value was less than the value of a game's virtual artefact the artefact was not available to the players and was marked in a red colour.

This budget constraint resulted in players being more cautious regarding the way they constructed, furnished and decorated their Sims family house in House 2 gameplay. The groups were making cost-effective b-decisions, such as creating a smaller-sized house and selecting cheap furniture and decorations. However, in order to make such b-decisions there was an interplay of their EU, MU and GVAs. As evidenced by the results presented in Chapter 6 and in particular in Table 6-2 and Table 6-3 (see Section 6.1.2.2, p.161), GVA,EU,MU combination increased greatly in House 2 gameplay in comparison to House 1 gameplay. Indeed, the groups were not just trying to construct a house for that family. They were trying to construct a functional cost-effective house, by considering the family's needs and the game's Build and Buy mode content (GVA) and by selecting the necessary furniture and appliances needed for a house to be functional (EU), considering their cost (MU) as there was a specific budget constraint (GVA and MU) such as the example of selecting tiles from M&C's gameplay that was described earlier in this section (see also Avraamidou, 2016). More examples of the interplay of GVA, EU and MU in players' gameplay are illustrated in the episodes presented in Sections 6.2.2.1, 6.2.2.2 and 6.2.2.3 of Chapter 6. I now turn my focus to another dynamic resource that is also an integral GVA of the game and was also important for players' House 2 gameplay: the game's Live mode menu.

7.2.1.2 The Live mode meters: a dynamic resource

All groups played at the beginning and mostly in the end of their House 2 gameplay with the Live mode of the game in order to select their virtual family and this influenced their gameplay. As shown in Chapter 6 (see Sections 6.2.4, in p.190) the content of the Live mode menu provided players with information regarding their Sims family needs and mood via specific meters. It also displayed information regarding their Sims interests, likes and dislikes. The displayed meters and information were GVAs that also became mobilised in gameplay. As they were proceeding with their gameplay, players could see their Sims' mood meter level changing and when it was low, they read information that was provided by the game in order to understand the reasons and act accordingly so as to increase the meter. This resulted in the emergence of sub-goals which guided players' actions towards making adjustments to the house they had created. The sub-goals that emerged as a result of the interpretations that players made from the Live mode meters were all pursued by the groups as making their Sims happy was considered important for the players, despite the issues and restrictions that some groups faced (see Section 6.2.4, in p.190).

The Live mode's mood and need meters are in fact artefacts with built-in relationships by the game's designers. Players in this study used their EU of a real person's needs in order to interpret the meanings of those meters and the way they worked in gameplay. Whilst making adjustments to their house, the Live mode and the Live mode's menu was a dynamic resource that provided instant feedback to players regarding their house's functionality in respect to the family's needs and interests as the Live mode's meters and interest were constantly changing. This is something that was also reported by Gee and Hayes (2010, p.156) where a player who created a virtual house in the Second Life digital game, which is also a simulation sandbox game, could set her avatar to "walk through it, view it from different angles, and make changes with immediate results".

7.2.2 Appropriating game's virtual artefacts: tools and instrumental genesis

The pre-set GVAs in this particular game were artefacts in the sense of Wartofsky's (1979, p.202) "primary artefacts"; artefacts that are "directly used in this production". Those GVAs were created by the game's designers to be used by players during their gameplay. Nonetheless, there were situations where players did not just use such "primary artefacts" as they were but appropriated them and used them to achieve their goals; they became "secondary artefacts", representations of the primary artefacts (Wartofsky, 1979, p.202). One of those moments where players appropriated GVAs was the one I referred to earlier in this chapter, whilst addressing RQ2 (see Section 7.1.2, p.211); the 'Create a Style' and 'Eyedropper' options, as two GVAs – options of the game that were used by A&E and S&K respectively, in their gameplay. The episodes of A&E and S&K's gameplay that illustrated the way those two options were used by the groups were presented earlier in Chapter 6 (See 6.2.2.5, p.181). Those two options were created by *The Sims 3* game designers as part of the structure of the game to allow players to customise GVAs that are in the game's menus and were already added in players' houses. It is worth mentioning that the 'Create a Style' and the 'Eyedropper' options of the game were always shown in the game's Build and Buy mode menus but only S&K explored both of them both during their gameplay. A&E only explored the 'Create a Style' and M&C and G&N never clicked on those game virtual artefact-options during their gameplay. A&E and S&K explored the game's menu more than the other two groups because they wanted their house to look good and were trying to find ways to change their house's appearance in a cost-effective way. I now shift my focus to these two episodes in order to illustrate the way A&E and S&K

appropriated such GVAs and used them as tools to decorate their family's house in House 2 gameplay without spending any money from the family's budget.

During their House 1 gameplay, A&E experimented with the 'Create a Style' GVA option of the game and realised what it did, by using it to change some of their House 1 GVAs' appearance. In House 2 gameplay, the girls sounded disappointed by their house's appearance and decided to decorate it with GVAs such as wallpapers and wall paints but they were having second thoughts because their desired wallpapers were quite expensive and they had a budget to consider. That moment, Eleni recalled the 'Create a Style'. When they tried to use it on the plain walls, the game did not allow them to use it (nothing happened) but then Eleni said: *"What if you add a wallpaper and then try it on it?"*. Eleni understood how that specific GVA worked in the game by realising the game's rule behind it: It does not customise plain walls but wall-decorations. When they tried it on a §5-cost wallpaper and it worked, Alexia suggested to use the 'Create a Style' on that §5-cost wallpaper but Eleni went a step further, recalling that there were §0 cost options for wallpapers and floor tiles, suggesting to use it on free cost (§0) wallpapers by saying: *"Now, wait… wait, try it with something that is free so that we won't get charged"*. That was because their initial goal was to decorate their house in a desirable, yet cost-effective way.

Similarly, during House 2 gameplay, S&K wanted to decorate their family's house but the wallpapers and tiles they liked were expensive. Thus they b-decided to use the free cost (§0) tiles for the house's floor and were also disappointed by the way their house's appearance looked like. The girls were exploring the game's menu and came across the 'Create a Style' and used it in order to change the appearance of the §0-cost floor tiles into a colour they liked. The girls tried to use the 'Create a Style' option on their house's walls but they were not allowed by the game, similarly to A&E's gameplay. However, S&K did not realise the rule that Eleni realised and as a result, S&K bought cheap (not free) and desirable wallpapers to decorate their walls and did not use the 'Create a Style' on their walls after all. However, the girls explored the game's menu even more and discovered the 'Eyedropper' option which is another game's virtual artefact-option that allows players to copy a specific style from a GVA that is placed in the house and paste it on another GVA, changing the latter's appearance this way. As soon as Katerina tried the 'Eyedropper' she realised what it could do, similarly to Eleni's realisation above, and suggested creating a pattern on their floor's tiles using both 'Create a Style' and 'Eyedropper' options, saying: *"No, no, look, we (should) change just this one with the style (Create a Style option) and then use the dropper (Eyedropper) to get the blue squares".* The girls managed to change the appearance of the whole house's floor in a desirable pattern without spending any money, using a combination of those GVA-features.

The use of the 'Create a Style' and the use of the 'Eyedropper' as described above are examples of the way a game's artefact became mobilised during players' gameplay. But there is more to these examples. These examples, illustrate the way players transformed those game's virtual artefacts into instruments, by understanding the affordances and the constraints and rules inherent in those artefacts developing "instrumental genesis and efficient procedures in order to manipulate the artefact" (Guin & Trouche, 1999, p.201). In respect to A&E's use of the 'Create a Style' artefact, Eleni used a GVA along with her knowledge regarding the way that artefact worked and her knowledge that there were free cost items in the game's menu. This artefact-option use and the accompanied knowledge turned an artefact that was designed by the game's designers to help players customise most GVAs' appearance in a tool that helped her and Alexia to change their house's appearance in a desirable way without spending any money which was important for their House 2, budget-constrained, gameplay. The use and appropriation of the 'Create a Style' by A&E as illustrated above, was an example of the way those players understood the game's rules regarding the use of that GVA-option, explored the relationships inherent in that GVA and its relationships with other GVAs (use on wallpapers not plain walls, use on §0-cost wallpapers to save on budget etc.) as prompted by their need to save on the budget but also their need to create a desired outcome.

Returning to the operational definition of mathematical thinking in this research (see the introduction of Section 7.1, p.205), players' gameplay activity was an "activity with relationships" (Noss & Hoyles, 1996a, p.124). The examples illustrated earlier in Section 7.2.1 of this section and the example of the use of the 'Create a Style' and 'Eyedropper' from A&E and S&K's gameplay that were discussed above are examples that illustrate the way players' mathematical thinking was employed whilst players explored the relationships inherent in the GVAs ('Create a Style', 'Eyedropper', budget, Live mode meters and GVAs in Build and Buy mode menu) as prompted by a need, influenced by their prior understandings (MU and EU) to save on the family's budget whilst creating a functional and – in A&E and S&K's case – a nice-looking virtual house for their Sims family.

7.2.3 A 'web' of resources

For this section I now recall Noss and Hoyles' (1996a) idea of "webbing" (see Chapter 2, Section 2.3.3, p.20) which "is meant to convey the presence of a structure that learners can draw upon and *reconstruct* for support – in ways that they choose as appropriate for their struggle to construct meaning for some mathematics" (p.108, emphasis of the original). Players in this research were asked to accomplish two quite open tasks set and articulated vaguely by the researcher. As mentioned earlier, each group's gameplay unfolded in a different way and the virtual houses they built were not the same. This is interrelated with the fact that players formed their own goals in order to accomplish those two tasks as this digital game is a sandbox game that does not have explicit goals. As they were creating the houses, players were making b-decisions in order to achieve (or abandon) the goals they had formed during their gameplay and these b-decisions were under their control. Nonetheless, as discussed earlier in Section 7.2.1 players' goals and b-decisions were shaped and influenced by an interplay of the following parameters: i. players' prior understandings, ii. players' interaction and iii. the game's virtual artefacts, rules and constraints in the two tasks. The interplay outlined above constituted a "web of connections" (Noss and Hoyles, 1996a, p.105) and this web was being enhanced as players proceeded with their gameplay. It constituted a support system, the structure of which allowed players to "draw upon and *reconstruct* for support – in ways that they choose as appropriate" in Noss & Hoyles' (1996a, p.108) idea of "webbing", whilst processing the goals they had formed during gameplay (see A&E appropriation of 'Create a Style' GVA-option in Section 7.2.2). During gameplay, players would use their prior understandings, both everyday and mathematical, what was available in the game's menus and rules and what they would take from their interaction with each other as elements to support their gameplay. Mathematical thinking was an element of this “web of connections” as it was identified in situations where players would use their mathematical prior understandings in order to explore relationships that were buried in the game’s virtual artefacts. In addition, as players were progressing through their gameplay, they became more familiar with the game and were also learning the game’s rules, mechanics and geography (Egenfeldt-Nielsen et al., 2008). .

The parameters involved in the interplay described above were parameters in Saxe’s emergent goal model (Saxe, 1991, see Chapter 2, Section 2.2.2, p.17); prior understandings, conventions and artefacts and social interaction. Saxe used this model in order to illustrate the way practice-linked goals emerged, in the context of candy selling practice in the streets of Brazil (Saxe, 1991). In this research, the parameters of this model were adapted and were used in order to analyse the way players’ goals were formed *and* were processed during gameplay in this particular context (see Chapter 3.2.2, p.53). As discussed earlier in Section 7.2.1 the results of this research showed (see Chapter 6, Section 6.1.2.2, p.161) that in processing sub-goals that involved the use of their mathematical prior understandings, players also drew upon their everyday prior understandings and the game’s virtual artefacts for support. The elements that players’ used for support echo Luckin’s (2010a, p.162) “Ecology of Resources” model of context that suggests that forms of assistance can be “Knowledge and Skills, Tools and People and the Environment”. In particular, Luckin (2010b, p.18) states that: “context is dynamic and associated with connections between people, things, locations and events in a narrative that is driven by people’s intentionality and motivations. Technology can help to make these connections in an operational sense. People can help to make these connections have meaning for a learner”. Yet this section (7.2) has illustrated that technology does not just help making such connections in an operational sense; the way all groups interacted with the technology (the game’s virtual artefacts) and, in particular, the way A&E appropriated ‘Create a Style’ artefact turning it into a tool to support their gameplay in a way it made sense to them, suggest that perhaps technology did more. This statement is preliminary and in need of further investigation but, perhaps, technology in this case helped to make these connections have a meaning to the player.

The section that follows explores the mathematics that arose in *The Sims 3* gameplay which, as it will be discussed next, were linked to the game's context.

7.3 'Blended mathematics': mathematics that arises in *The Sims* 3 gameplay

As illustrated and discussed in Sections 7.1 and 7.2 earlier, players used mathematics during their gameplay because there was a need to use mathematics in order to proceed with their goal-directed actions. However, recalling literature relevant to mathematics in out-of-school settings, mathematics brought into and used by players during gameplay was mathematics in the context of the particular game and it was *"inextricably linked to their [players] working context"* (Maganja & Monaghan, 2003, p.120). In this section I first discuss the mathematics that arose in *The Sims 3* gameplay and argue that it was 'blended mathematics'; mathematics that was blended with players' everyday understandings and the game's (and players') virtual artefacts. I then argue that the blended mathematics that arose in *The Sims 3* gameplay were influenced by the task (House 1 and House 2) that was set to the groups, the game's virtual artefacts and rules and the discourse that players had whilst being engaged in their gameplay activity.

When players used their mathematical prior understandings in order to process their sub-goals it was always 'blended' with either the game's and/or the players' virtual artefacts, players' everyday prior understandings or game's rules. The 'blended mathematics' term was something that I first introduced in my MA dissertation (Avraamidou, 2007) and further discussed in Avraamidou, Monaghan and Walker (2012) which was based on that research. At this point, I briefly present the example used for illustrating 'blended mathematics' that emerged in Costas' (the boy who played *The Sims* 2 game in my MA dissertation) gameplay. Whilst Costas was building a virtual house for a Sims family, he had created a swimming pool which he wanted the family to be able to view from inside their house. Costas wanted to select doors for the family's living room and bedroom veranda so as to be able to view the swimming pool he had created. After going through the game's menu (game's virtual artefacts) to view and compare the cost (mathematical prior understandings) of the available options he selected glass doors which were not cheap options but allowed the family to view the swimming pool (everyday prior understandings) because “it suited his family’s needs, which was the object of his activity” (Avraamidou, Monaghan & Walker, 2012, p.16).

Similarly to Costas’ b-decision, players in this research also made b-decisions in which mathematics was blended. In particular, recalling the results presented in Chapter 6 (Table 6-2, p.162), in order to proceed with the majority of their goal-directed actions that involved their mathematical prior understandings, players used their mathematical and everyday prior understandings and the game’s virtual artefacts in synergy. An extract from A&E’s House 2 gameplay that was illustrated earlier in Chapter 6 (Table 6-11, p.176) will now be discussed as an example of the blended mathematics in players’ gameplay. The girls were, at that time, talking about items that would be necessary for their House 2 kitchen and they were discussing the necessity of a dishwasher. The girls did not buy a dishwasher which was expensive but appreciated the combination of a sink and a bench as something necessary for the functionality of the family’s house and their family’s everyday activity. They reached their b-decision of buying a stand-alone sink and a bench for the family in House 2 gameplay after using their everyday prior understandings of a real life house’s kitchen which is equipped with a sink to wash the dishes and also a bench to let them dry them, in combination with their mathematical prior understandings of comparing the cost of the available menu options (game’s virtual artefacts) and selecting a cost-effective option. Thus, they reached that b-decision because it was a cost-effective b-decision which was important for the budget-constrained House 2 gameplay but it was at the same time a decision that suited their Sims family’s needs, which was their task; to create a house for a Sims family.

In the example of A&E’s House 2 gameplay that was presented above, the girls did not just compare numbers to select the lowest sum and did not just talk about, move and arrange 3D objects in a 3D software environment. They were talking about the properties of 3D objects that were designed by the game’s developers as game’s virtual artefacts and were simulating real life objects. They were comparing the cost of game’s virtual artefacts which were kitchen furniture that had a specific use and function in that (virtual) house and this mattered. The girls in the above example, b-decided to select a sink and then placed a bench right next to the sink because they wanted the family to be able to "dry their plates after using them" which is an everyday activity of a real-life household. Their kitchen was a room that consisted of several 3D objects, each one of them selected because its properties (i.e. cost, size, shape, appearance and so on) were realised by players and were assessed whilst blending their prior understandings (everyday and mathematical) with the game's content and rules.

Overall, during their gameplay, players were manipulating 3D objects which were game virtual artefacts. They explored and talked about the properties of those 3D objects, such as their size, shape and – in House 2 gameplay – cost and they were moving and arranging those objects in a virtual terrain which had a grid but they were not doing it in a school-like mathematics' way; they were not using a dynamic geometry software that involves geometrical objects and relationships and they did not have specific school-like tasks and problems set by teachers that guided and accompanied their onscreen activity (Laborde, 2002). Players were dragging and manipulating 3D objects, they were exploring their properties and relationships and they were using mathematics and mathematical thinking in a way that is not 'privileged' in formal school curriculum activities (Wertsch, 1991, p.124), where students use school-mathematics and dynamic geometry software in order to solve specific school-like tasks are (i.e. Laborde, 2002; Hoyles & Noss, 2003; Ruthven, Hennessy & Deaney, 2008). Players in this study were "experiment[ing] with geometrical objects and relationships" in unpredicted ways (Hoyles & Noss, 2003, p. 333) in a dynamic digital environment that was designed as a digital game and was played in out-of-school settings. They were using the game's virtual artefacts and their properties in order to accomplish two open tasks that were set by the researcher (not a teacher) but were highly associated with and linked to the game's context; create a virtual house (task 1) and create a virtual house for a Sims family (task 2) in the game's context. I now explore further the influence of the task on the way mathematics arose in players' gameplay.

The above examples of 'blended mathematics' in *The Sims* series gameplay both arose in more constrained gameplay, where a family and a family's budget were involved. The task (task 2) influenced the way blended mathematics arose in players' gameplay, because in House 2, players' gameplay was more constrained as their task involved a Sims family which had a budget constraint and certain needs. As discussed earlier in Sections 7.1.1 and 7.1.2 such constraints in players' gameplay influenced players' mathematical thinking that emerged in their gameplay; they had to consider the size and structure of their house; they had to consider the number, cost and type of the items they bought for the family; they had to think of ways of saving on the family's budget and the groups that spent all the budget had to think of ways of increasing the budget's balance in order to proceed. Furthermore, recalling the results related to the mathematical prior understandings code presented in Chapter 5 (Table 5-6, p.139) earlier, in more constrained gameplay, players' used their prior mathematical understandings more often in comparison to less constrained gameplay in order to process their sub-goals. In addition, recalling the results in Chapter 6 (Table 6-2, p.162), in more constrained gameplay the majority of the mathematical prior understandings was blended with players' everyday prior understandings and the game's (and/or players') virtual artefacts. Therefore, the constraints that emerged in the second task stimulated a more frequent and blended use of players' mathematical prior understandings during gameplay. But there was more to that because players created their houses collaboratively and were interacting with each other through their talk, which was also influenced by the task. I now focus this section on players' talk and the way it was influenced by the task during gameplay.

Players' talk during gameplay was a mediation that facilitated players' interaction and process of setting and sharing goals whilst collaboratively – for most of the time – proceeding with their task during gameplay. It was also a resource because players were explicitly sharing and explaining their thoughts to one another in situations that required players to negotiate their next moves, building on each other's ideas before reaching to a joint b-decision. Such situations occurred when players were processing sub-goals using talk that was mostly coded as *Exploratory Talk* (Mercer, 2010). The discussion made earlier in Subection 7.1.3 drawing on the results of Chapter 5 (Section 5.3.2, p. 147 and Table 5-6, p.139) showed that players' use of *Exploratory Talk* was higher in more constrained gameplay (House 2) than in less constrained gameplay (House 1) in all groups, similarly to the increase of the codes for players' mathematical prior understandings. In Chapter 6 (Table 6-4, p.164) I examined more closely the sub-goals in which players' talk was coded as *Exploratory* and they involved players' mathematical prior understandings. The results (see Table 6-4, p.164) showed that in constrained gameplay (House 2) the majority of the sub-goals where players used their *Exploratory Talk* were processed with actions involving players' mathematical prior understandings. Nonetheless, only in less than half of the sub-goals where player's mathematical prior understandings were employed, players used *Exploratory Talk* to process them.

Therefore, when players were processing sub-goals which required them to use their mathematical prior understandings they were not necessarily explaining their ideas to each other, but when they were in situations where unexpected issues occurred in which they had to negotiate their next moves and explain their suggestions in order to make sense of those situations, they used their mathematical prior understandings in order to process those sub-goals and proceed with their gameplay. There were two type of situations which stimulated players' *Exploratory Talk* during gameplay: i. players used *Exploratory Talk* in order to negotiate the structure, content, appearance and functionality of their virtual houses based on their personal preferences (for example, episodes illustrated in Chapter 6, Sections 6.2.1.2, 6.2.1.3, 6.2.4.2) and ii. players used *Exploratory Talk* when they were challenged and when they faced restrictions, constraints and issues during their gameplay (for example, episodes illustrated in Chapter 6, Sections 6.2.1.1, 6.2.2.4 and 6.2.3). The second type of situations occurred mostly when players goals were in conflict with the game's rules and/or the game's virtual artefacts such as the family's budget and needs. As shown earlier in Section 7.1.3, the second type of situations mainly involved unexpected challenges and constraints and were "breakdown moments". Such moments occurred mostly in the second task (House 2 gameplay) in which the budget-constraint was enabled and caused players to explore the mathematical relationships inherent in the GVAs and it was in such moments that players' mathematical thinking became more "visible" to the researcher, similarly to Noss, Hoyles & Pozzi (1998, p.117) findings regarding the "visibility" of mathematics in-use in workplace settings. Yet it was in such moments where players used *Exploratory Talk* in order to: make sense of those situations, negotiate and understand the meanings of the relationships and the rules that constrained their gameplay in both tasks, form new sub-goals, share their mathematical and everyday prior understandings to each other that made the mathematics and the mathematical thinking that arose in their gameplay, “visible” (see for example the episodes in Chapter 6, Sections 6.2.2 - 6.2.3, pp.173 – 185).

7.4 Gameplay in an open-world, real-life simulation sandbox game

Sections 7.1, 7.2 and 7.3 in this Chapter, illustrated and discussed players’ gameplay in *The Sims 3* with a focus on mathematics and mathematical thinking that arises during gameplay. This brief Section discusses players’ gameplay focusing on the open-world, real-life simulation sandbox game characteristics of *The Sims 3* game. For this section, I recall literature that was reviewed earlier in Section 2.4.4 (Chapter 2, p.36). Returning to Squire’s (2008, p. 107) argument that “we need rigorous research into what players do with games (particularly those that don’t claim explicit status as educational) and a better understanding of the thinking that is involved in playing them” I briefly discuss what players did in terms of the open-world, real life simulation and sandbox characteristics of this game.

The Sims 3 is an open-world game that allows players to set their own goals and explore the game’s content. The four groups in this research were given two tasks by the researcher. However those two tasks were not designed or modified by the researcher. Those two tasks were integrated activities that Sims series players do and were open tasks that each group interpreted and accomplished in different ways. Indeed, as discussed earlier in Sections 7.1.1.1 and 7.1.4 each group set their own goals and as they proceeded with their gameplay and interacted with the game’s content, rules and constraints, goals emerged along the way. In addition, as discussed earlier in Section 7.2, players’ activity was ‘webbed’ (Noss and Hoyles, 1996a) and players used available resources and tools at hand. However, each groups’ use of such resources and tools varied because each group set their own goals, explored the game’s content differently and depending on their previous actions, their own understanding of the game’s rules and constraints varied. Even though all groups created the virtual houses and three of the four groups selected the same family from the inventory of the game, the outcome was not the same because the process each group followed was not the same, the rules and constraints that each group encountered was similar but some groups encountered more constraints than others and the resources and tools used by each group varied. This is a key characteristic of the complex and unpredictable gameplay of an open-world sandbox game (Tornqvist, 2015).

The Sims 3 game is also a real life simulation game and it represents family relationships, buy-sell transactions with its own currency system and real life objects. Therefore, inherently, this game requires players to use their everyday life experiences regarding the way a house is built, furnished and decorated, the way family relationships work and the way nurturing a person's needs is important for his/her survival (Nutt & Railton, 2003; Montes & Cambell, 2013). As discussed earlier in Section 7.2.1, players' everyday prior understandings were used as a resource during their gameplay. All houses included rooms and furniture that can be found in real world houses. Yet, when there were no budget constraints, players created relatively large and expensive houses with luxurious items in a way that can be characterised as exaggerating. However, in House 2 gameplay, where budget constraints were enabled, players were responsible for creating a virtual family's house and attend to their needs with a certain budget to spend, as it happens in real life. As it was discussed earlier in Section 7.2.1 in such constrained gameplay players recalled their everyday experiences in respect to what is essential for a house to be functional and cost-effective and what is important for a person to live. For example, I recall M&C's gameplay episode (Chapter 6, Section 6.2.3.2, p.187) where they decided to delete parts of the house in order to increase the budget so as to be able to buy a toilet for their family because it is one of our everyday needs and as Marios stated: "Where are they going to go when they will want to go to the toilet?". The way players in this research proceeded with creating their virtual houses in this real-life simulation game confirms what Nutt & Railton (2003, p.577) argued when the first version of this game was released: "players are active agents negotiating both the game's version of real life and their own real-life experiences".

Lastly, *The Sims 3* is a sandbox digital game that allows players to edit the onscreen environment. As discussed in Sections 7.1.1 and 7.2.2, the game's designers created – in particular – the game's Build and Buy mode menus, options and tools in a way that can support players' goals and gameplay as they create, edit and delete items in the onscreen environment so as to create, furnish and decorate their virtual houses. Due to the open-ended nature of this game, game designers provided options that players could use in order to customise the game's artefacts, such as the 'Create a Style' and 'Eyedropper' options (see relevant episode in Chapter 6, Section 6.2.2.5, p.181). When creating houses from scratch in *The Sims 3* game, players think of the structure of the house and the way they would place game virtual artefacts such as foundations, walls, furniture and so on in a way that would eventually form a house. Since the game is an open-world sandbox simulation, players can do that in an *Exploratory* way (Tornqvist, 2015), such as in House 1 gameplay, but when the constraints of the game increase, such as in House 2 gameplay, players encounter challenges and their own goals are more constrained by the game's rules and restrictions, such as the budget constraint. Thus, in a more constraint open-world sandbox simulation gameplay, players' goals are affected by the constraints and players' thinking involves goal-directed actions that emerge during gameplay whilst players are trying to understand those constraints and negotiate their own goals with what is allowed by the game and its constraints. Yet, as discussed in Section 7.2.2, in situations where players' goals were constrained by the game's rules, players used and appropriated integral game's virtual artefacts such as the 'Create a Style' and 'Eyedropper' customisation options, in order to achieve their goals. Such creativity and such player-generated artefacts are enabled in sandbox games that allow players to edit the onscreen environment as it was reported for example in research related to the creations of Minecraft's mods (Al-Washimi et al., 2014), the activities of *The Sims* 'Skinners' (Wirman, 2011) and 'Modders' (Sihronen, 2011).

In concluding, there is no doubt that the way players' gameplay unfolded in this, open-world, real-life simulation sandbox, game was complex and not easily predictable. Looking at the final products, the eight overall virtual houses that players created during their gameplay varied yet were considered as 'completed' by the players as they were 'satisfied' with the final outcome, because they were the ones who owned this activity. Herrington et al. (2014, pp.401-402) refer to authentic learning as "a pedagogical approach that situates learning tasks in the context of real-world situations, and in so doing, provides opportunities for learning by allowing students to experience the same problem-solving challenges in the curriculum as they do in their daily endeavors". Although I do not argue that the kind of challenges players faced during their gameplay in this research were the same as in the curriculum, the open-ended nature of this game and the sandbox characteristics both enabled and constrained players' gameplay and as gameplay became more constrained several – and often complicated – challenges emerged. Players had to interact with each other using the available resources and tools at hand in order to overcome them (see Sections 7.1.2 and 7.2) and because this game is a real life simulation, representing elements and situations of real life, the kind of challenges that players encountered during gameplay were relevant to real life processes, requiring players to bring their everyday prior understandings during gameplay. I do not know whether players in this research will use in the future the experience they gained through budget-related challenges and the whole house building and virtual characters' nurturing activity. Nonetheless, I argue that due to the open-world, real-life simulation sandbox characteristics that were explored in this research, *The Sims 3* game might facilitate authentic learning.

7.5 Summary

This chapter addressed the general question and the four research questions of this thesis in Section 7.1. Whilst addressing those research questions, three themes emerged which were discussed in separate sections. Section 7.2 discussed the interplay of players' gameplay, mathematical and everyday prior understandings and the game's virtual artefacts and rules that characterised players' gameplay, arguing that this interplay acted as a 'web' of resources for players and illustrating incidences of players' instrumental genesis during gameplay. Section 7.3 discussed the way mathematics that arose in players' gameplay was 'blended mathematics' that was inextricably linked to the game's context, was influenced by the task and the constraints of gameplay. Lastly, Section 7.4 discussed players' gameplay focusing on the open-world, real-life simulation sandbox characteristics of *The Sims 3* game. A more detailed account of the key findings discussed in this chapter is given in the Conclusions chapter that follows.

Chapter 8 – Conclusions

Following the Discussion Chapter where the research questions of this thesis were addressed and findings were discussed, this chapter starts with an overview of the thesis' key findings in Section 8.1, which leads to a discussion of the contributions and implications of this thesis in research inquiry in Section 8.2, the limitations of this research in Section 8.3 and further research and scholarship suggestions in Section 8.4.

8.1 Key findings of this research

The aim of my thesis was to explore out-of-school collaborative gameplay in an open-world real life simulation sandbox digital game, *The Sims 3*, focusing on the emergence of players' mathematical thinking during their gameplay. Specifically, bringing together findings of prior research related to: i. mathematics in out-of-school settings such as workplace settings (Noss, Pozzi & Hoyles, 1998; Magajna & Monaghan, 2003) and in the streets (Saxe, 1991), ii. socio-cultural frameworks and theories related to the use of artefacts, tools and resources in activities (Leont'ev, 1981; Saxe, 1991), iii. gameplay of commercial digital games and, in particular, open-world sandbox games such as Civilization (Squire, 2006) and Minecraft (MacCallum-Steward, 2013) and iv. results from my MA dissertation (Avraamidou, 2007) which investigated players' mathematical meanings in *The Sims* series gameplay, I set the following four research questions:

1. What potential is there for mathematical thinking in The Sims 3 as a game?

2. How does players' mathematical thinking emerge and how is it influenced when players engage in a less constrained and in a constrained gameplay?

3. How do players collaborate during a less constrained and during a constrained gameplay?

4. How do players' goal-directed actions emerge during The Sims 3 gameplay?

The first research question was designed in order to explore and identify elements of *The Sims 3* that would potentially facilitate players' mathematical thinking during gameplay. The second and third research questions were linked to the task-design of this research as it was designed to uncover the effect of more constraints during gameplay on players' mathematical thinking and their interaction with each other. Considering that *The Sims 3* game is an open-world sandbox game that allows players to set their own goals during gameplay, the fourth research question aimed to explore the way players' goal-directed actions emerged during gameplay.

Although the thesis' findings are discussed in more detail in Chapter 7, I briefly summarise the key findings that emerged whilst addressing the four research questions, in order to discuss the contributions of these findings to research in the next section of this chapter:

- The potential for mathematical thinking in *The Sims 3* as a game, lies in the mathematical relationships that are buried in the digital artefacts, rules and restrictions, designed by the game's designers and developers. Yet, consistent with previous research in workplace settings (Noss & Hoyles, 1996a), these mathematical relationships became mobilised during gameplay, through players' goal-directed actions.

- Players' mathematical thinking did emerge both in less and in more constrained gameplay in *The Sims 3*. This finding confirms Devlin's (2011, p.127) argument that commercial games "do require that players carry out certain kinds of mathematical thinking". Nonetheless, this research showed that players' mathematical thinking did not just emerge, but it was also shaped and influenced when players' gameplay was constrained by the game's rules and restrictions, as players encountered problematic situations. In particular, the involvement of a Sims family and the budget constraint that was enabled in House 2 gameplay resulted in influencing players' thinking in respect to their house's structure (size, shape and number of rooms), furniture and equipment (cost and necessity) and decoration (appearance in relation to cost). Players' actions were directed by goals that players set whilst considering the budget of the family and the cost of the game's virtual artefacts before selecting them during House 2 gameplay.

- Compatible with arguments that open-world sandbox gameplay is complex and unpredictable (Tornqvist, 2015), the gameplay of players in this research unfolded in a complex way as well. Even though the four groups' gameplay was driven by the same two tasks, the pathways that each group followed and the final houses they built varied. Nonetheless, examining the way players' goals emerged during gameplay, following an adaptation of a socio-cultural model developed by Saxe (1991) whilst exploring the activity of children selling candies in the streets, shed some light. Even though players were engaged in an activity which was set in a virtual world, players were interacting with an open-ended sandbox game that it is also a real life simulation game. These characteristics of *The Sims 3* game, as discussed earlier in Section 7.4 (p.238) allowed players to set their own goals in a world where real life activities such as constructing a house, buying and selling items and interacting with other (virtual) characters are simulated. The findings of this research show that the parameters that influenced the goals that players formed during gameplay, were broadly in line with Saxe's parameters of emergent goals.

- Specifically, the formation and processing of players' goals which directed their actions during gameplay were mostly characterized and influenced by an interplay of: i. the game's virtual artefacts, rules and restrictions, ii. players' everyday and mathematical prior understandings and iii. players' interaction with each other. In fact, in Section 7.2 (p.223), I argued that this interplay consisted a supportive system for players during gameplay, that acted as a 'web' of resources, in the sense of Noss & Hoyles (1996a) idea of 'webbing'. Drawing on this 'web' of resources, players would set new goals that directed their actions and in 'breakdown' moments (Noss, Hoyles and Pozzi, 1998, p.108) and in situations where players' initial plans needed to be redevised, players drew on elements of this 'web' of resources for support. In particular, players drew on their mathematical prior understandings and employed mathematical thinking as a resource to help them resolve issues that were mostly arosen in House 2 budget-constrained gameplay that involved a family and its budget. In this bounded task of creating a budget-constrained house, players could draw on information received by the virtual family and their virtual interaction with it. Having a family that was virtually available for players to interact with, play with and get feedback from as they were building House 2, assisted players in ensuring that the house was accessible and functional, but most importantly: making *The Sims* family happy by seeing the mood meter rising.

- The above interplay revealed that mathematics that arose in *The Sims 3* game was, as I discuss in Section 7.3 (p.233), 'blended mathematics'; mathematics that was blended with players' everyday prior understandings and the game's (and players') virtual artefacts. The results of this thesis are consistent with and confirm the results and findings of my MA dissertation, in which I referred to the term 'blended mathematics'. However, the findings of this thesis expand the previous findings by arguing that the way 'blended mathematics' arose in gameplay was influenced by the task and the constraints of gameplay that varied in the two tasks.

- The 'blended mathematics' that arose in *The Sims 3* gameplay was inextricably linked to the game's context and was not easily identifiable by the researcher. Nonetheless, it became more 'visible' as players were negotiating solutions to overcome unpredicted – problematic – situations that emerged during their gameplay. These findings are comparable, and in the same line, with findings of research investigating mathematics in workplace (i.e. Pozzi, Noss & Hoyles, 1998; Magajna and Monaghan, 2003; Triantafillou & Potari, 2010).

- The findings of my research provide evidence and support what Devlin's (2011,p.165) suggested referring to game designers who want to design games for mathematical thinking, arguing that they should focus on "the development of real-world-applicable mathematical thinking involving everyday mathematics that the learner can make immediate use of in the world". This particular commercial real-life simulation game supported players' "real-world-applicable mathematical thinking involving everyday mathematics" and everyday prior understandings. Although this research does not provide evidence to support that players will eventually use in the real world, this research does have evidence that such thinking emerged during gameplay.

- Nonetheless, because of the advancements in technology and the design of the data collection process of this research, I was able to record players' talk whilst playing the game. This allowed me to explore players' talk in terms of Mercer's (2010) type of talk framework. The findings of this research argue that in more constrained gameplay and in unexpected – problematic – situations that emerged during their gameplay, players' talk was mostly coded as *Exploratory*. In particular, during more constrained gameplay and in situations where players shared and explained their thoughts and understandings of the situation to each other, players used their mathematical prior understandings in order to negotiate their actions. In such situations and through players' *Exploratory Talk*, 'blended mathematics' became more 'visible' (Noss & Hoyles, 1996a) to the researcher.

- Lastly, there were incidences where players were undergoing instrumental genesis (Guin & Trouche, 1999) in gameplay. The open-world nature of *The Sims 3* game allowed players to set their own goals. There were players who, whilst processing such goals and exploring the game's virtual artefacts, took advantage of the game's sandbox nature in order to appropriate certain game's virtual artefacts, such as the 'Create a Style' and 'Eyedropper' options and used them as tools so as to achieve their goals (see Subection 7.2.2).

Despite the diversity of the gameplay pathways that players-participants of this research followed in order to accomplish the two open tasks of creating virtual houses in *The Sims 3* game, the key findings of this research contribute to various areas of research inquiry. The thesis' contributions are discussed next.

8.2 Contributions and Implications of this research

This research contributes and adds to existing knowledge in three main research areas which are related to: i. mathematics and mathematical thinking in out-of-school settings, ii. commercial digital games and mathematics learning in out-of-school settings and iii. artefacts, resources and tools in object-oriented activities in virtual worlds. It has implications for game designers who aim in designing games for mathematical thinking and for researchers who design studies investigating (mathematics) learning in open-world sandbox digital games. In addition, the methodology and data analysis methods that were designed and employed in this research add to existing knowledge regarding methodologies for collecting and analysing data of gameplay in open-world and sandbox games with a focus on learning. The seven main elements of my research which I have identified as my contributions are discussed next.

Firstly, researchers who investigated the potentials of commercial digital games in respect to education and learning argued that there is a need for rigorous research examining what players actually do and what kind of thinking is involved in such games (Squire, 2008; Young et al., 2012). So far, to my knowledge, there has not been an in-depth examination of what players do and think whilst playing commercial digital games in respect to mathematical thinking and, in particular, in open-world sandbox games which are played in out-of-school settings. This research explored players' gameplay and focused on the emergence of players' mathematical thinking as they were building virtual houses in an open-world, real-life simulation sandbox game. This thesis provided an account of what players did during gameplay and discussed the way players' complex and unpredictable gameplay unfolded. Furthermore, this research reviewed theoretical ideas regarding mathematical thinking and provided an operational definition that was used in order to identify mathematical thinking in the context of commercial digital games' gameplay.

Secondly, research has already argued that mathematics emerge in settings outside school such as in workplace settings (i.e. Noss, Pozzi & Hoyles, 1998; Noss &

Hoyles, 1996a; Magajna & Monaghan, 2003), in the streets (i.e. Saxe, 1991; Nunes et al., 1993) and in everyday activities (i.e. Lave, 1988). Although playing commercial digital games *is* a popular everyday activity of both adult and children (ESA, 2016), research investigating mathematics that emerges and is used in the activity of playing commercial digital games in out-of-school settings is limited (Avraamidou, Monaghan & Walker, 2015). Bringing theoretical frameworks and ideas from research of mathematics in out-of-school settings and adapting Saxe's (1991) mode of emergent goals, this research provided an insight of the way mathematics arises in the context of an open-world, real-life simulation sandbox game and argued that such mathematics was 'blended mathematics'. Expanding the definition of the term 'blended mathematics' that I firstly used in my MA dissertation (see Avraamidou, 2007), in this research I specified the parameters involved in 'blended mathematics' making it inextricably linked to the context of a game.

Thirdly, this study adds to existing knowledge regarding the 'visibility' of "mathematics-in-activity" (Noss & Hoyles, 1996a, p.34) by arguing that in the context of gameplay, breakdown moments and "mathematics-in-activity" can be found in the form of challenges and problematic situations that emerge during gameplay and argued that 'blended mathematics' becomes more 'visible' whilst players are trying to understand and overcome such challenges during gameplay. This research adds knowledge to these ideas by providing evidence that in the context of digital games, such breakdown moments and problematic situations are linked to the constraints that are related to the game's mechanics and rules and as the constraints increase during gameplay, the mathematical thinking is influenced.

Fourthly, this study's findings can inform game design as it contributes to research that explores the development of digital games that can facilitate and develop mathematical thinking. In this particular real-life simulation game, mathematical thinking did emerge but it was not predesigned by the game's creators. Mathematical thinking emerged because players had to carry out mathematical thinking and was influenced when players were engaged in more constrained gameplay. In this study, less and more constrained gameplay were highly linked to the two open tasks that enabled specific rules and restrictions which were originally built in the particular game. This study's findings suggest that the potential for mathematical thinking lies in the mathematical relationships that are hidden in the game's artefacts, rules and restrictions which are designed by the game's creators. The open-world nature of this game allowed players to explore such relationships and the game's restrictions and rules resulted in fostering such thinking. Nonetheless, the rules and restrictions built in the game mechanics should not be too difficult to achieve. They need to be challenging but manageable by players so as to stimulate players' thinking but at the same time such challenges must be high and in balance with what players can do, so as to keep players engaged in gameplay (Schernoff, Csikszentmihalyi, Schneider and Shernoff, 2003), enabling them to devise plans that are possible to implement during gameplay.

Fifthly, the findings of this study add to existing knowledge regarding user-generated artefacts in virtual worlds. This game is a sandbox game that allows players to create virtual artefacts using the game's default virtual artefacts. My research revealed that, in combination with the game's rules and restrictions, players underwent instrumental genesis (Guin & Trouche, 1999) in gameplay, appropriating existing game's virtual artefacts, turning them into tools to help them proceed with their gameplay and overcome the challenges.

Sixthly, this research adds knowledge to existing research investigating the use of mathematics and mathematical thinking in activities that occur in out-of-school and without a teacher's intervention. In particular, participants in this research played a digital game in out-of-school settings and as shown, in the process, they encountered several challenges and problematic situations that required them to use their mathematical prior understandings and carry out mathematical (and other) thinking so as to overcome them. They did not have a teacher to scaffold their gameplay and guide them towards this process. Rather, the findings of this research argue that, in order to achieve the goals they had formed themselves and proceed with their gameplay, players drew upon a 'web' of resources (Noss & Hoyles 1996a) that involved themselves and their prior understandings, their interaction with each other and the game's virtual artefacts, rules and restrictions. This is something that can potentially have implications for educators and it is worth investigating further.

Lastly, due to the originality of this research and the lack of previously implemented research design, apart from my MA dissertation (Avraamidou, 2007), a great challenge I faced was related to the design of the research methodology and the methods of data collection and analysis. I believe that the research design of this research, as illustrated in Chapter 3 (p.49), contributes to the qualitative research field that involves exploration of players' activity in such open-world, simulation, sandbox games with a focus on learning. The use of screen recording software allowed me to collect rich data as players were being engaged in the activity of playing a digital game. This has implications for qualitative researchers because the employment of such technological advancements, allowed me to record players' onscreen activity whilst simultaneously capturing their talk led to the collection of audio-visual data that was not easy to analyse, yet could be replayed and analysed many times. I believe that the process of the six stages of analysis I designed and implemented in order to make sense of my data and address this thesis' research questions can be followed and adapted accordingly, by other researchers who intend to explore the emergence of mathematics and mathematical thinking in the activity of playing open-world, simulation, sandbox digital games.

8.3 Limitations of this research

This research has several limitations that are important to bring forward and briefly discuss in this section.

Firstly, this study followed four groups in their gameplay of a particular digital game. Therefore, the number of participants was, despite the diversity in age and sex, small. However, whilst designing this research I acknowledged the limitation in respect to making generalisations and I aimed at understanding the way mathematics arises in the bounded case study of playing this digital game (Yin, 2009).

Secondly, the two tasks that players were asked to go through were open tasks that a Sims series' player can go through whilst playing this particular game. As shown by the results of this research, these open-ended tasks provided an insight of the way players' interacted with the game's mechanics and the game's environment but at the same time resulted in diverse outcomes as each groups' final virtual houses varied. This resulted in limitations in making case-study comparisons of the four groups' gameplay.

Thirdly, players' onscreen activity and their talk were recorded using screen recording software. This provided rich data. However, as reported in the results of this research, there were times where players revealed emotions whilst playing the game which could potentially lead to affect research in this context but were not clearly captured by their voice. Most of the screen recording software, such as the one I used, allows for camera recordings of players' behaviour whilst interacting with a computer. Nonetheless, in this research I did not use a video camera to record participants because they were children and this would raise ethical issues (Cohen et al. 2011). However, perhaps in future research that has a focus on affect, enabling this additional option can help in acquiring richer data.

Fourthly, I did not use any instruments to collect data regarding players' mathematical thinking competence or regarding their performance in school-mathematics before gameplay. Therefore, I cannot argue that the kind of mathematics that players' used in their gameplay was linked to their school-performance. Similar to this limitation, I did not have a follow up session to see if *The Sims 3* gameplay had an effect in their everyday lives, as this was not in the scope of this research.

Fifthly, I did not use any instruments to collect data regarding players' demographics such as their social class, their own houses and their buying habits. Thus, I could not focus deeper on sociological aspects such as the effect of players' buying preferences and habbits on their gameplay buying selections. Nonetheless, it was acknowledged that such sociological analysis was not a primary focus of this study. Furthermore, I did not collect any data regarding players' gaming preferences and prior experience with digital games. Having collected such data could have allowed me to gain a deeper understanding of players' gameplay, because players' prior experience with digital games affect their interaction with new digital games (Bourgonjon, Valcke, Soetaert & Schellens, 2010).

Sixthly, the findings reported in this study derived from the selected methodology and analysis framework. It is acknowledged that had I selected other ways of analysing gameplay data, such as Gee's (2014, p.1) proposed *unified discourse* *analysis* which is a new type of discourse analysis that "studies language, games, science, and human action and interaction in the real world and in imaginary ones", I may have obtained different findings. Nonetheless, by the time this model was publicly available, the data of this study was already collected following the selected methodology.

Lastly, it is acknowledged that the results of this research are limited to the context of this particular game. The kind of mathematical thinking that emerged and was influenced during gameplay was highly linked to the specific context and game elements of this particular game.

8.4 Suggestions for further research and scholarship

Considering this study's findings, contributions and limitations there are several ways that this research could be taken further. The suggestions that follow are drawn from this study and refer to recommendations for further research inquiry and suggestions for widening scholarship.

Firstly, this study provided an insight of players' gameplay activity and thinking in *The Sims 3* digital game. It explored the way mathematics arose in an open-world sandbox digital game and have argued that mathematical thinking lied in the mathematical relationships that were hidden in the artefacts, rules and restrictions of this particular game. Further research should be conducted so as to explore the way mathematics and mathematical thinking emerges in popular digital games such as Minecraft, in order to examine whether this study's findings extend in other popular commercial open-world sandbox digital games as well.

Secondly, players in this study played with all three modes of *The Sims 3* during their gameplay, but the majority of their gameplay activity was whilst they were playing with the Build and Buy modes of the game. However, gameplay in the Live mode of this game is worth investigating even further, by examining the way players attend to a Sims virtual family's needs and handle a virtual household's budget as their Sims virtual characters grow older.

Thirdly, this study produced a framework for exploring players' gameplay activity by analysing their goal-directed actions and talk during gameplay, building on

Saxe's (1991) socio-cultural theoretical model of emergent goals. This study's analysis framework can be replicated by other researchers who seek to explore mathematics that arises in open-ended gameplay activity. In respect to this particular game, because it is a real-life simulation game, the findings of this study suggest that further research can be employed so as to explore whether other subjects, such as science and social studies, can emerge in *The Sims 3* gameplay.

Lastly, the results and findings of this study illustrated the way players' prior understandings, players' interaction with each other and with the game's virtual artefacts, rules and restrictions, acted as a supporting 'web' of resources (Noss & Hoyles, 1996a) for players during their gameplay. Traditional views of Vygotsky's 1978) zone of proximal development a learner can be supported to go further whilst working on a task or solving a problem during his/her interaction with a more experienced person, such as "*adult guidance or* [...] *a more capable peer*" (ibid, p.86, italics in original). Expansions of Vygotsky's zone of proximal development suggest that there is a bi-directional development between the learner and the adults or more capable peers that are involved in this process (Ferhold & Lecusay, 2009). Nonetheless, in this study, players went through open tasks, formed their own goals and experienced unexpected problematic situations during gameplay in out-of-school settings where there was not a teacher's intervention. In addition, players in each pair were of the same age and all players played this digital game for the first time. Therefore, there was neither "adult guidance" nor "a more capable peer" to support them during gameplay. However, the way two of the groups appropriated the 'Create a Style' and 'Eyedropper' artefacts of the game and used them as tools in order to overcome unexpected problematic situations during their gameplay suggests that there was a bi-directional development process shared between players and the game's virtual artefact during gameplay. This is something that is worth exploring further as there could be a possible widening of scholarship in relation to the zone of proximal development.

References

Ackermann, E. (2001) Piaget's Constructivism, Papert's Constructionism: What's the difference? In *Constructivism: Uses and Perspectives in Education* (pp.85-94). Conference Proceedings, Geneva: Research Center in Education.

Adams, C., & van Manen, M. (2008). Phenomenology. In L. M., Given (Ed.). *The Sage Encyclopedia of Qualitative Research Methods* (pp. 614-619). London: Sage.

Adams, E., & Rollings, A. (2003). *Andrew Rollings and Ernest Adams on game design*. USA: New Riders Publishing.

Ahlfeldt, S., Mehta, S., & Sellnow, T. (2005). Measurement and analysis of student engagement in university classes where varying levels of PBL methods of instruction are in use. *Higher Education Research and Development*, 24(1), 5–20. doi: 10.1080/0729436052000318541

Al – Washmi, R., Bana, J., Knight, I., Benson, E., Kerr, O. A. A., Blanchfield P., & Hopkins, G. (2014). Design of a math learning game using a Minecraft mod. In I. C. Busch (Ed.), *Proceedings of the 8th European Conference on Games Based Learning* (Vol. 1, pp. 10-17). Reading, UK: Academic Conferences International Limited.

Andreassen, S. & Syvertsen, A. (2016). Playful Learning with The Sims, for Adult Learners. In T. Conolly & L. Boyle (Ed) *Proceedings of The 10th European Conference on Games Based Learning* (pp. 933 – 938). Reading, UK: Academic Conferences International Limited.

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M. T. (2009a). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers & Education, 53*(1), 74-85. doi: 10.1016/j.compedu.2008.12.020

Annetta, L., Mangrum, J., Holmes, S., Collazo, K., & Cheng, M. T. (2009b). Bridging Realty to Virtual Reality: Investigating gender effect and student engagement on learning through video game play in an elementary school classroom. *International Journal of Science Education, 31*(8), 1091-1113. doi: 10.1080/09500690801968656

Argyle, S.F. (2012) *Mathematical Thinking: From Cacophony to Consensus* (Unpublished doctoral dissertation). Kent State University, Kent, OH

Avraamidou, A. (2007). *Exploring the construction of mathematical meanings through game play of the commercial video game: The Sims 2.* (Unpublished Master dissertation). University of Leeds, UK.

Avraamidou, A. (2012). Exploring the construction of mathematical meanings through gameplay of "The Sims 2" video game in out-of-school settings. In C. Vrasidas & P. Panaou (Eds.), *Proceedings of the 62nd International Council for Educational Media Conference*. (pp. 137-146). Nicosia, Cyprus: ICEM.

Avraamidou, A. (2016). Instances of mathematical thinking through collaborative gameplay. In *Ninth Congress of the European Society for Research in Mathematics Education* (pp. 2453-2459). Prague: Charles University in Prague, Faculty of Education and ERME.

Avraamidou, A., Monaghan, J., & Walker, A. (2012). Abstraction through game play. Technology, Knowledge and Learning, 17(1–2), 1–21. doi: 10.1007/s10758-012-9189-2

Avraamidou, A., Monaghan, J. & Walker, A. (2015). Mathematics and Non-School Gameplay. In T. Lowrie, R. Jorgensen (Zevenbergen) (Eds.), *Digital Games and Mathematics Learning, Mathematics Education in the Digital Era 4*, (pp. 11-34). New York: Springer.

Barbieri, M., & Light, P. (1992). Interaction, gender and performance on a computer problem-based task. *Learning and Instruction*, *2*(3), 199–213.

Barnett, M., Squire, K., Higgenbotham, T., & Grant, J. (2004) Electromagnetism supercharged! In Y., Kafai, W., Sandoval, N., Enyedy, A. Dixon & F. Herrera, (Eds.) *International Conference of the learning sciences.* (pp. 513-520). Lawrence Erlbaum.

Bogost, I. (2007). *Persuasive Games: The Expressive Power of Videogames*. Cambridge: MIT Press.

Bonanno, P., & Kommers, P. A. M. (2008). Exploring the influence of gender and gaming competence on attitudes towards using instructional games. *British Journal of Educational Technology, 39*(1), 97–109. doi: 10.1111/j.1467-8535.2007.00732.x

Bonotto, C. (2013). Artifacts as sources for problem-posing activities. *Educational Studies in Mathematics*, 83(1), 37–55.

Bourgonjon, J., Valcke, M., Soetaert, R., & Schellens, T. (2010). Students' perceptions about the use of video games in the classroom. *Computers & Education, 54*(4), 1145-1156. doi: 10.1016/j.compedu.2009.10.022

Buckingham, D., & Scanlon, M. (2002). *Education, edutainment, and learning in the home*. Cambridge: Open University Press.

Burton, L. (1984). Mathematical Thinking: The Struggle for Meaning. *Journal for Research in Mathematics Education, 15*(1), 35-49. doi: 10.2307/748986

Caillois, R. (1961). *Man, play, and games*. New York: The Free Press, Glencoe.

Candy, P. C. (1989). Alternative paradigms in educational research. *The Australian Educational Researcher, 16*(3), 1-11.

Chen, C. P. (2001). On exploring meanings: combining humanistic and career psychology theories in counseling. *Counseling Psychology Quarterly*, *14*(4), 317-331. doi: 10.1080/09515070110091308

Chuang, T.Y. & Chen, W.F. (2009). Effect of Computer-Based Video Games on Children: An Experimental Study. *Educational Technology & Society,* 12**,** 1-10.

Clark, D., Nelson, B., Sengupta, P., & D'Angelo, C. (2009, October). Rethinking science learning through digital games and simulations: Genres, examples, and evidence. Paper commissioned for the *National Research Council Workshop on Games and Simulations*, Washington, DC.

Cohen, L., Manion, L. & Morrison, K. (2011). *Research Methods in Education* (7th ed.). London: Routledge

.

Common Sense Media (2011). *Zero to eight: Children's Media Use in America*. Retrieved from: https://www.commonsensemedia.org/file/zerotoeightfinal2011pdf-0/download

Connolly, T.M., Boyle, E.A., MacArthur, E., Hainey, T. & Boyle, J.M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education,* 59, 661-686. doi: 10.1016/j.compedu.2012.03.004

Cowely, B., Darryl, C., Black, M., & Hickey, R. (2008). Toward an understanding of flow in video games. *Computers in Entertainment, 6* (2), article no 20. doi: 10.1145/1371216.1371223

Crawford, C. (1984). *The Art of Game Design.* California: McGraw Hill/Osborne Media

Crawford, C. (2003). *On Game Design.* Peachpit: New Riders.

Creswell, J.W. (2007). *Qualitative inquiry & research design: choosing among five approaches* (2nd Ed.). London: Sage Publications.

Crotty, M. (1998). *The Foundation of social research: Meaning and perspective in the research process.* London: Sage Publications.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. New York: Harper and Row

Davydov, V. V. (1985). Leont'ev's theory of the relationship between activity and mental reflection. *Journal of Russian and East European Psychology*, 23(3), 28-45.

Davydov, V. V. (1990). *Types of generalization in instruction: Logical and psychological problems in the structuring of school curricula.* Reston, VA: National Council of Teachers of Mathematics (Original work published in 1972).

Denis, G., & Jouvelot, P. (2005). *Motivation-driven educational game design: applying best practices to music education.* Paper presented at the 2005 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology, Valencia, Spain. Retrieved from: http://dl.acm.org/citation.cfm?id=1178581

Denzin, N.K. & Lincoln, Y.S. (Eds). *Handbook of qualitative research* (2nd ed). California: Thousand Oaks, Sage Publications.

Devlin, K.J., (2011). *Mathematics education for a new era: video games as a medium for learning*. Massachusetts: A.K. Peters.

Diaper, D. (2008). Reactionary reactions to altering activity theory. *Interacting with Computers, 20*(2)**,** 260-266. doi: 10.1016/j.intcom.2007.10.001

Dicks, B., Soyinka, B. & Coffey, A. (2006). Multimodal ethnography. *Qualitative Research.* 6(1), 77-96. doi: 10.1177/1468794106058876

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E., Spada, & P., Reiman, (eds), *Learning in humans and machine: Towards an interdisciplinary learning science*, (pp. 189–211). Oxford: Elsevier.

Duncan, S. C. (2011). Minecraft, beyond construction and survival. In D. Davidson (Ed.) *Well Played: A journal on video games, value and meaning*, (pp.1-22). Retrieved from: http://press.etc.cmu.edu/files/WellPlayed-v1n1-11-web.pdf

Edwards, A. (2011) *Cultural Historical Activity Theory* (British Educational Research Association on-line resource). Retrieved from: https://www.bera.ac.uk/wp-content/uploads/2014/03/Cultural-Historical-Activity-Theory-CHAT.pdf

Edwards, J. A., & Lampert, M. D. (Eds.) (1993). *Talking data: Transcription and coding in discourse research*. Hillsdale, New Jersey: Erlbaum.

Egenfeldt-Nielsen, S. (2005). *Beyond edutainment: exploring the educational potential of computer games* (Unpublished doctoral dissertation), IT University, Copenhagen, Denmark.

Egenfeldt-Nielsen, S. (2006). Overview of research on the educational use of video games. *Digital Kompetanse*. 3(1), 184-213.

Egenfeldt-Nielsen, S., Smith, J.H. & Tosca, S.P. (2008). *Understanding Video Games: the essential introduction*. London: Routledge.

Embong, R., Aziz, N.M.A., Wahab, Z.A. & Maidinsah, H. (2010). An Insight into the Mathematical Thinking of the Malay Songket Weavers. *Procedia Social and Behavioral Sciences, 8*, 713-720. doi: 10.1016/j.sbspro.2010.12.099

Emmison, M. & Smith, P. (2000). *Researching the Visual*. Thousand Oaks, CA: Sage.

Engeström, Y. (1999). Expansive visibilization of work: An activity theory perspective. *Computer Supported Cooperative Work* 8(1), 63–93. doi: 10.1023/A:1008648532192

Engeström, Y. (2001). Expansive learning at work: Towards an activity theoretical reconceptualization. *Journal of Education and Work*, 14(1), 133–156.

ESA (2010). *2010 essential facts about the computer and video game industry*. Retrieved from: http://isfe.eu/sites/isfe.eu/files/attachments/esa_ef_2010.pdf

ESA (2011). *2011 essential facts about the computer and video game industry.* Retrieved from: http://www.theesa.com/facts/pdfs/ESA_EF_2011.pdf

ESA (2012). *2012 essential facts about the computer and video game industry*. Retrieved from: http://www.isfe.eu/sites/isfe.eu/files/attachments/esa_ef_2012.pdf

ESA (2013). *2013 essential facts about the computer and video game industry*. Retrieved from: http://www.isfe.eu/sites/isfe.eu/files/attachments/esa_ef_2013.pdf

ESA (2014). *2014 essential facts about the computer and video game industry*. Retrieved from: http://www.theesa.com/wp-content/uploads/2014/10/ESA_EF_2014.pdf

ESA (2015). *2015 essential facts about the computer and video game industry*. Retrieved from: http://www.theesa.com/wp-content/uploads/2015/04/ESA-Essential-Facts-2015.pdf

ESA (2016). *2016 essential facts about the computer and video game industry*. Retrieved from: http://essentialfacts.theesa.com/Essential-Facts-2016.pdf

European Commission (2011). *Mathematics Education in Europe: Common Challenges and National Policies*. Belgium: Education, Audiovisual and Culture Executive Agency

Fettermam, D. (2008). Ethnography. In L.M., Given, (Ed.). *The Sage Encyclopedia of Qualitative Research Methods.* London: Sage

Fisher, E. (1992) Characteristics of children's talk at the computer and its relationship to the computer software. *Language and Education,* 7(2), 97-114. doi: 10.1080/09500789309541351

Flick, U. (2002). *An introduction to qualitative research* (2nd ed.). London: Sage.

Flick, U., von Kardoff, E. & Steinke, I. (2004). *A companion to qualitative research.* London: Sage (translated by Bryan Jenner)

Gall, M.D., Borg, W.R., & Gall, J.P. (1996). *Educational research: an introduction.* (6th ed.). New York: Longman.

Garcia Martinez, S. (2014). *Using commercial games to support teaching in higher education* (Unpublished doctoral dissertation). Concordia University, Quebec, Canada

Gee, J. (2003). *What video games have to teach us about leanring and literacy.* New York: Palgrave MacMillan.

Gee, J.P. (2007). *Good video games and good learning: Collected essays on video games, learning and literacy (New literacies and digital epistemologies).* New York: Peter Lang Publications

Gee, J.P., & Hayes, E. R. (2010). *Women and gaming: The Sims and 21st century learning*. New York: Palgrave Macmillan.

Gee, J.P. (2014). *Unified Discourse Analysis : Language, Reality, Virtual Worlds and Video Games*. Milton Park, Abingdon, Oxon: Routledge

Given, L.M., (2008, Ed.). *The Sage Encyclopedia of Qualitative Research Methods.* London: Sage

Gonzalez, V. (2006). *The Nature of managing multiple activities in the workplace*. (Unpublised doctoral dissertation), University of California, Irvine.

Greenfield, P., M. (1994). Video games as cultural artifacts. *Journal of Applied Developmental Psychology,* 15**,** 3-12.

Greenstein, S., Panorkou, N. & Seventko, J. (2016). Optimizing teacher and student agency in Minecraft-mediated mathematical activity. In M.B., Wood, E.E., Turner, M., Civil, & J.A., Eli, (Eds.). *Proceedings of the 38th annual meeting of the North American Chapter of the International Group for the Psyschology of Mathematics Education* (pp.1541-1544). Tucson, AZ: The University of Arizona

Gresalfi, M., Martin, T., Hand, V. & Greeno, J. (2008). Constructing competence: an analysis of student participation in the activity systems of mathematics classrooms. *Educational Studies in Mathematics*, *70*(1), 49-70. doi: 10.1007/s10649-008-9141-5

Guillen-Nieto, V. & Aleson-Carbonell, M.A. (2012). Serious games and learning effectiveness: The case of *It's a Deal!. Computers & Education, 58*(1), 435-448. doi: 10.1016/j.compedu.2011.07.015

Guin, D., & Trouche, L. (1999). The complex process of converting tools into mathematical instruments. The case of calculators. *The International Journal of Computers for Mathematical Learning, 3*(3), 195–227. doi: 10.1023/A:1009892720043

Hämäläinen, R. (2008). Designing and evaluating collaboration in a virtual game environment for vocational learning. *Computers and Education*, 50(1), 98–109. doi: 10.1016/j.compedu.2006.04.001

Hämäläinen, R., & Vähäsantanen, K. (2011). Theoretical and pedagogical perspectives on orchestrating creativity and collaborative learning. *Educational Research Review, 6*, 169 – 184. doi: 10.1016/j.edurev.2011.08.001

Hamlen R, K. (2011). Children's choices and strategies in video games. *Computers in Human Behavior,* 27**,** 532-539. doi: 10.1016/j.chb.2010.10.001

Hanghøj, T., Hautopp, H., Jessen, C., & Denning, R. C. (2014). Redesigning and reframing educational scenarios for Minecraft within mother tongue education. In I. C. Busch (Ed.), *Proceedings of 8th European Conference on Games Based Learning* (pp. 182-190). Reading, UK: Academic Conference and Publishing International Limited.

Harel, G. (2008a). DNR Perspective on Mathematics Curriculum and Instruction: Focus on Proving, Part I. *ZDM—The International Journal on Mathematics Education, 40*, 487-500. doi: 10.1007/s11858-008-0104-1

Harel, G. (2008b). DNR Perspective on Mathematics Curriculum and Instruction, Part II. *ZDM—The International Journal on Mathematics Education*, *40,* 893-907. doi: 10.1007/s11858-008-0146-4

Harel, G., Selden, A., & Selden, J. (2006). Advanced mathematical thinking. In A. Gutiérrez & P., Boero, (Eds.) *Handbook of research on the psychology of mathematics education* (pp.147-172). Rotterdam, Netherlands: Sense Publishers

Herrington, J., Reeves, T. & Oliver, R. (2014). Authentic Learning Environments. In J.M. Spector, M.D. Merrill & M.J. Bishop (Eds.) *Handbook of Research on Educational Communications and Technology* (pp.401-412). New York: Springer

Hershkowitz, R., Schwarz, B., & Dreyfus, T. (2001). Abstraction in context: Epistemic actions. *Journal for Research in Mathematics Education*, 32(2), 195–222.

Higgs, J. (2001). Charting standpoints in qualitative research. In H. Byrne-Armstrong, J. Higgs, & D. Horsfall (Eds.), *Critical moments in qualitative research* (pp. 44-67). Oxford, England: Butterworth-Heinemann.

Hill, J. R., & Hannafin, M. J. (2001). Teaching and learning in digital environments: The resurgence of resource-based learning. *Educational Technology Research and Development, 49*(3), 37-52. doi: 10.1007/BF02504914

Howe, C., Tolmie, A., Thurston, A., Topping, K., Christie, D., Livingston, K., et al. (2007). Group work in elementary science: towards organisational principles for supporting pupil learning. *Learning & Instruction*, *17*(5), 549 - 563. doi: 10.1016/j.learninstruc.2007.09.004

Howson, G. (2008, April 16). The Sims is biggest selling PC game 'franchise' ever. *The Guardian.* Retrieved from: https://www.theguardian.com/technology/gamesblog/2008/apr/16/simsbiggestsellingpcgamei

Hoyles, C. (2003, June). *From Instrumenting and Orchestrating Convergence to Designing and Recognising Diversity: A response to Luc Trouche*. Plenary presentation at the Third Computer Algebra in Mathematics Education Symposium, Reims, France

Hoyles, C., & Noss, R. (2003). What can digital technologies take from and bring to research in mathematics education? In A. J. Bishop, M. A. Clements, C. Keitel, J. Kilpatrick, & F. Leung (Eds.), *Second International Handbook of Mathematics Education* (pp. 323-349). Dordrecht: Kluwer Academic Publishers.

Pozzi, S., Noss, R., & Hoyles, C. (1998). Tools in practice, mathematics in use. *Educational Studies in Mathematics, 36*(2), 105-122. doi: 10.1023/A:1003216218471

Hoyles, C., Noss, R., & Pozzi, S. (2001). Proportional reasoning in nursing practice. *Journal for Research in Mathematics Education*, *32*(1), 4-27. doi: 10.2307/749619

Hsiao, H-C. (2009). Reflective Learning through Playing Digital Game and The Sims 2. In M. Chang et al. (Eds.) *Learning by Playing. Game-based Education System Design and Development Proceedings of the 4th International Conference on E-learning, Edutainment 2009* (pp. 220-227), Banff, Canada.

Hughes, E. C. (1971). *The sociological eye.* Chicago: Aldine

Huizinga, J. (1950) *Homo Ludens*. Boston: The Beacon Press.

Husserl, E. (1998) *The essential Husserl: basic writings in transcendental phenomenology.* Bloomington, IN Indiana University Press (edited by Welton, D.)

ISFE (2012). *Videogames in Europe: Consumer Study, European Summary Report.* Retrieved from: http://www.isfe.eu/sites/isfe.eu/files/attachments/euro_summary_-_isfe_consumer_study.pdf

Iversen, S.M. (2014). Paradox and pleasure: Play with everyday life in a ludic simulation. *MedieKultur, Journal of media and communication research*, *56*, 100-116. doi: 10.7146/mediekultur.v30i56.18502

Johnson, D., & Johnson, R. (1985). Motivational processes in cooperative, competitive, and individualistic learning situations. In C. Ames & R. Ames (Eds.), *Research on motivation in education: The classroom milieu* (Volume 2, 249–286). New York: Academic Press

Juul, J. (2002). The Open and the Closed: Games of emergence and games of progression. In F. Mäyrä, (Ed.) *Computer Game and Digital Cultures Conference Proceedings*. (pp. 323-329). Tampere, Tampere University Press

Juul, J. (2003). The game, the player, the world: Looking for a heart of gameness. In M., Copier, & J., Raessens, (Eds.) *Level Up: Digital Games Research Conference*, Utrecht, Utrecht University.

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. In R. E. Ferdig (Ed.), *Handbook of research on effective electronic gaming in education* (Vol. 1, pp. 1–32). Hershey, PA: Information Science Reference

Kebritchi, M., & Hirumi, A. (2008). Examining the pedagogical foundations of modern educational computer games. *Computers & Education, 51*(4), 1729-1743. doi: 10.1016/j.compedu.2008.05.004

Kirriemuir, J., & McFarlane, A. (2004). *Literature review in games and learning: A report for NESTA Futurelab*. Retrieved from: https://hal.archives-ouvertes.fr/hal-00190453/document

Knoblauch, H., Schnettler, B. & Raab, J. (2006). Video-Analysis. Methodological Aspects of Interpretive Audiovisual Analysis in Social Research. In H., Knoblauch, J.R., Schnettler, & H., Soeffner, (Eds.) *Video analysis methodology and methods: Qualitative Audiovisual Data Analysis in Sociology* (pp.9-26). Frankfurt: Peter Lang

Krauss, S. E. (2005). Research paradigms and meaning making – a primer. *The Qualitative Report, 10*(4), 758 – 770. Retrieved from: http://nsuworks.nova.edu/tqr/vol10/iss4/7/

Kuutti, K. (1991). Activity theory and its applications in information systems research and design. In H.E., Nissen, H.K., Klein, & R., Hirschheim, (Eds.). *Information Systems Research Arena of the 90s, Challenges, Perceptions and Alternative Approaches* (p. 529-550). Amsterdam: North-Holland.

Kuutti, K. (1995). Activity Theory as a potential framework for human-computer interaction research. In B. Nardi (Ed.). *Context and Conciousness: Activity Theory and Human Computer Interaction.* (pp. 17-44). Cambridge: MIT Press.

Laborde, C. (2002). Integration of technology in the design of geometry tasks with Cabri-geometry. *International Journal of Computers for Mathematical Learning, 6*, 283–317. doi: 10.1023/A:1013309728825

Lakatos, I. (1976). Proofs and Refutations. Cambridge: Cambridge University Press

Lane, C. P., & Harkness, S. S. (2012). Game show mathematics: Specializing, conjecturing, generalizing, and convincing. *Journal of Mathematical Behavior*, *31*(2), 163-173. doi: 10.1016/j.jmathb.2011.12.008

Lave, J. (1988). *Cognition in practice*. Cambridge: Cambridge University Press

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge: Cambridge University Press.

Leont'ev, A. N. (1981). The problem of activity in psychology. In J. V., Wertsch (Ed.), *The concept of activity in Soviet psychology* (p. 37-71). New York: Sharpe

Leont'ev, A.N (1974). The problem of activity in psychology. *Soviet Psychology 13*(2), 4–33.

Leont'ev, A.N. (1978). Activity, consciousness, and personality. Englewood Cliffs: Prentice-Hall.

Lewis, Winer, Kellert & Chao (2015). Elementary students' spatial reasoning in a Minecraft environment. In T.G., Bartell et al. (Eds.) *Proceedings of the 37th annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. (p. 309). East Lansing, MI: Michigan State University

Leyland, B. (1996). *How can computer games offer deep learning and still be fun?* Paper presented at the Ascilite Conference (pp. 375-380), Adelaide, Australia. Retrieved from: http://www.ascilite.org/conferences/adelaide96/papers/14.html

Lindley, C. A., Nacke L., & Sennersten C. C. (2008). *Dissecting Play – Investigating the Cognitive and Emotional Motivations and Affects of Computer Gameplay.* Paper presented in the *13th International Conference on Computer Games conference*, Wolverhampton, UK. Retreived from: https://pdfs.semanticscholar.org/70b7/14a71b0c065d1bd8a9b9bd18f5740945f90e.pdf

Lofland, J., & Lofland, L. (1996). *Analyzing social settings* (3rd ed.). Belmont, California: Wadsworth.

Logan, T. & Woodland, K. (2015). Digital Games and Mathematics Learning: The State of Play. In T. Lowrie & R. Jorgensen (Zevenbergen) (Eds.), *Digital Games and Mathematics Learning, Mathematics Education in the Digital Era 4*, (pp. 277-304). New York: Springer

Lowrie, T. & Jorgensen, R. (Zevenbergen) (2015). *Digital Games and Mathematics Learning, Mathematics Education in the Digital Era 4.* New York: Springer

Luckin, R. (2010a) Learning Contexts as Ecologies of Resources: A Unifying Approach to the Interdisciplinary Development of Technology Rich Learning Activities. *International Journal On Advances in Life Sciences*, *2*(3&4),154-165. doi: 10.1007/s11423-015-9369-6

Luckin, R. (2010b) *Re-designing Learning Contexts: technology rich, learner-centered ecologies*. London, Routledge

MacCallum-Steward, E. (2013). Diggy Holes and Jaffa Cakes: The rise of the elite fanproducer in video-gaming culture. *Journal of Gaming & Virtual Worlds, 5*(2), 165-182. doi: 10.1386/jgvw.5.2.165_1

MacDonald, R., & Miell, D. (2000). Musical conversations: collaborating with a friend on creative tasks. In R. Joiner, K. Littleton, D. Faulkner, & D. Miell (Eds.). *Rethinking collaborative learning* (pp. 65-78). London: Free Association Books.

Magajna, Z. & Monaghan, J. (2003). Advanced mathematical thinking in a technological workplace. *Educational Studies in Mathematics,* 52(2), 101-122. doi: 10.1023/A:1024089520064

Marklund, B. B., Backlund, P., & Johannesson, M. (2013). Children's collaboration in emergent game environments. In *Proceedings of the International Conference on the Foundations of Digital Games* (pp. 306-313). New York, NY: ACM

Mason, J., Burton, L. & Stacey, K. (1982) *Thinking Mathematically*. London: Addison-Wesley

May, T. (2002). *Qualitative Research in Action.* London: Sage

McInnerney, J., & Robert, T.S., (2004). Collaborative or cooperative learning? In T.S., Roberts, (Ed.), *Online collaborative learning: Theory and practice*, (pp. 203–214). Hershey, Pennsylvania: Information Science Publishing

Mercer, N. (1995). *The Guided Construction of Knowledge.* Clevedon: Multilingual Matters.

Mercer, N. (2005). Sociocultural discourse analysis: Analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics*, *1*(2), 137–168. doi: 10.1558/japl.v1i2.137

Mercer, N. (2010). The analysis of classroom talk: Methods and methodologies. *British Journal of Educational Psychology, 80*(1), 1-14. doi: 10.1348/000709909X479853.

Merriam, S. (2002). *Qualitative Research in Practice: examples for discussion and analysis*. San Francisco: Jossey-Bass.

Mezirow, J. (1994). Understanding transformation theory. *Adult Education Quarterly*, *44*(4), 222-232. doi: 10.1177/074171369404400403

Michael, D. & Chen, S, (2006). *Serious Games: Games that Educate, Train, and Inform.* Boston (USA): Thomson Course Technology PTR.

Miller, M. & Hegelheimer, V. (2006). The Sims meet ESL Incorporating authentic computer simulation games into the language classroom. *Interactive Technology & Smart Education, 3*(4), 311-328. doi: 10.1108/17415650680000070

Miller, P. (2008). Ethnography. In L.M. Given, (Ed.). *The Sage Encyclopedia of Qualitative Research Methods.* London: Sage

Millroy, W.L. (1992). An Ethnographic Study of the Mathematical Ideas of a Group of Carpenters. *Journal for Research in Mathematics Education. Monograph*, *5*, i-x+1-210

Minecraft GamePedia (2017). *Gameplay*. Retrieved from: http://minecraft.gamepedia.com/Gameplay

Mitchelmore, M. & White, P. (2007) Editorial: abstraction in mathematics learning. *Mathematics Education Research Journal*, 19 (2), 1-9. doi: 10.1007/BF03217452

Monaghan (2016a) Tools, Human Development and Mathematics. In J.D. Monaghan, L. Trouche & J.M. Borwein (Eds.) *Tools and Mathematics: Instruments for learning*. (pp. 91-116) Switzerland: Springer.

Monaghan, J. (2007). Linking school mathematics to out-of-school mathematical activities: student interpretation of task, understandings and goals. *International*

Electronic Journal of Mathematics Education. 2 (2), 50-71. Available online at: http://www.iejme.com

Monaghan, J.D. & Trouche, L. (2016) Introduction to the book. In J.D. Monaghan, L. Trouche & J.M. Borwein (Eds.) *Tools and Mathematics: Instruments for learning*. (pp. 3-12) Switzerland: Springer.

Monaghan, J.D. (2016b) Tools and Mathematics in the Real World. In J.D. Monaghan, L. Trouche & J.M. Borwein (Eds.) *Tools and Mathematics: Instruments for learning*. (pp. 333-356) Switzerland: Springer

Montes, R.M. & Campbell, A.A. (2013) Dismantling the Digital Dollhouse: Will Wright's The Sims and Virtual Consumption. *Quarterly Review of Film and Video*, *30*(1), 41-49, doi: 10.1080/10509208.2010.544980

Nardi, B.A. (1996). Activity theory and human–computer interaction. In B.A. Nardi, (Ed.), *Context and Consciousness: Activity Theory and Human–Computer Interaction* (pp.7-16). USA: MIT Press.

National Council of Teachers of Mathematics (NCTM) (2009). *Focus in high school mathematics:Reasoning and sense making*. Reston, VA: Author.

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

Nebel, S., Schneider, S., & Rey, G. D. (2016). Mining Learning and Crafting Scientific Experiments: A Literature Review on the Use of Minecraft in Education and Research. *Educational Technology & Society*, *19* (2), 355–366.

Nguyen, L.A. (2014) Exclusive: Flappy Bird Creator Dong Nguyen Says App 'Gone Forever' Because It Was 'An Addictive Product'. *Forbes: Tech*. Retrieved from: https://www.forbes.com/sites/lananhnguyen/2014/02/11/exclusive-flappy-bird-creator-dong-nguyen-says-app-gone-forever-because-it-was-an-addictive-product/#7e3143856476

Niemeyer, D.J. & Gerber, H.R. (2015) Maker culture and Minecraft: implications for the future of learning. *Educational Media International*, 52(3), 216-226. doi: 10.1080/09523987.2015.1075103

Noss, R. & Hoyles, C. (1996a). *Windows on mathematical meanings: Learning cultures and computers.* London: Kluwer.

Noss, R., & Hoyles, C. (1996b). The visibility of meanings: Modelling the mathematics of banking. *International Journal of Computers for Mathematical Learning*, 1(1), 3–31. doi: 10.1007/BF00191470

Noss, R., Hoyles, C. and Pozzi, S. (2002). Abstraction in Expertise: A study of nurses' conceptions of concentration. *Journal for Research in Mathematics Education. 33*(3), 204-229. doi: 10.2307/749725

Nunes, T., Schliemann, A.D. & Carraher, D.W. (1993), *Street mathematics and school mathematics.* Cambridge: Cambridge University Press.

Nutt, D. & Railton, D. (2003) The Sims: Real Life as Genre. *Information, Communication & Society, 6*(4), 577-592, doi: 10.1080/1369118032000163268

Otten, S., Herbel-Eisenmann, B.A. & Males, L.M. (2010). Proof in algebra: Reasoning beyond examples. *Mathematics Teacher*, *103*(7), 514–518.

Papert, S. (1993). *The children's machine: Rethinking school in the age of the computer.* New York: Basic Books.

Papert, S. (1999). What is Logo and Who Needs It? In *Logo Philosophy and Implementation* (pp. iv – xvi). Logo Computer Systems Inc. Retrieved from: http://www.microworlds.com/company/philosophy.pdf

Patton, Q. (2002). *Qualitative Research and Evaluation Methods* (3rd ed.) London: Sage.

Piaget, J. (1978). *Success and understanding.* Cambridge: Harvard University Press.

Pirie, S. E. B. (2001). Analysis, lies, and videotape. In R. Speiser, C. A. Maher, & C. N. Walter (Eds.), *Proceedings of the Twenty-Third Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.* (Volume I, pp. 346–350). Columbus, Ohio: ERIC Clearinghouse for Science, Mathematics, and Environmental Education.

Polya, G. (1945). *How to solve it.* Princeton: Princeton University Press.

Polya, G. (1954). *Mathematics and Plausible Reasoning Volume I: Induction and Analogy in Mathematics.* Princeton: Princeton University Press.

Powell, A. B., Francisco, J. M. & Maher, C. A. (2003). An analytical model for studying the development of learners mathematical ideas and reasoning using videotape data. *Journal of Mathematical Behavior, 22*, 405 – 435.

Pratchett, R. (2002, October 11). Happy Families. *The Guardian*. Retrieved from: https://www.theguardian.com/technology/2002/oct/10/games.onlinesupplement1

Prensky, M. (2001). *Digital game-based learning.* New York; London: McGraw-Hill.

Ranalli, J. (2008). Learning English with The Sims: exploiting authentic computer simulation games for L2 learning. *Computer Assisted Language Learning, 21*(5), 441-455. doi: 10.1080/09588220802447859

Reiber, L. (1996). Seriously considering play: Designing interactive learning environments based on the blending of microworlds, simulations and games. *Education and Technology Research and Development, 44*(2)**,** 42-58. doi: 10.1007/BF02300540

Ridgway, J. (1988). *Assessing mathematical attainment.* Windsor: NFER-Nelson

Rogoff, B. & Lave, J. (1984). *Everyday cognition: Its development in social context,* Cambridge, MA: Harvard University Press.

Rogoff, B., & Lave, J. (Eds.). (1984). *Everyday cognition: Its development in social context*. Cambridge, MA: Harvard University Press

Roschelle, J., & Teasley, S. (1995). The construction of shared knowledge in collaborative problem solving. In C.E., O'Malley, (Ed.), *Computer supported collaborative learning* (pp. 69–97). Heidelberg: Springer-Verlag.

Russell, S. J. (1999). Mathematical reasoning in the elementary grades. In L. V. Stiff & F. R. Curcio (Eds.), *Developing mathematical reasoning in grades K–12* (pp. 1–12). Reston, VA: National Council of Teachers of Mathematics.

Ruthven, K., Hennessy, S. & Deaney, R. (2008). Constructions of dynamic geometry: A study of the interpretative flexibility of educational software in classroom practice. *Computers & Education, 51*, 297-317. doi:10.1016/j.compedu.2007.05.013

Ryan, G.W., & Bernard, H.R. (2000). Data management and analysis methods. In N.K. Denzin and Y.S. Lincoln (Eds), *Handbook of qualitative research* (2nd ed., pp.769-802). Thousand Oaks, California: Sage Publications.

Sáez-López, J. M., Miller, J., Vázquez-Cano, E., & Domínguez-Garrido, M. C. (2015). Exploring Application, Attitudes and Integration of Video Games: MinecraftEdu in Middle School. *Educational Technology & Society, 18* (3), 114–128. Available online from: http://www.ifets.info

Salen, K. (2008). *The ecology of games: Connecting youth, games and learning*. Cambridge, MA: MIT Press

Salen, K., & Zimmerman, E. (2003). *Rules of play: Game design fundamentals*. Cambridge: MIT Press.

Sandford, R., Ulicsak, M., Facer, K., & Rudd, T. (2006). *Teaching with games: Using commercial off-the-shelf computer games in formal education*. Bristol: Futurelab.

Saxe, G. B. (1991). *Culture and cognitive development: Studies in mathematical understanding.* Hillsdale, New Jersey: Laurence Erlbaum Associates.

Saxe, G. B. (1999). Cognition, development, and cultural practices. *New Directions for Child and Adolescent Development,* 83, 19-35. doi: 10.1002/cd.23219998304

Saxe, G. B., & Esmonde, I. (2004). Making change in Oksapmin trade stores: Studies in shifting practices of quantification under conditions of rapid social change. *South Pacific Journal of Psychology, 15*(1), 11-28. doi: 10.1017/S0257543400000134

Schliemann, A.D. & Carraher, D.W. (2002). The Evolution of Mathematical Understanding: Everyday Versus Idealized Reasoning. *Developmental Review, 22*(2), 242-266. doi: 10.1006/drev.2002.0547

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense-making in mathematics. In D. Grouws (Ed.), *Handbook* *for Research on Mathematics Teaching and Learning* (pp. 334-370). New York: MacMillan.

Schwandt, T.A. (2000). Three epistemological stances for qualitative inquiry: Interpretivism, hermeneutics, and social constructionism. In N.K. Denzin and Y.S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., p.189-213). London: Sage Publications.

Scribner, S. (1986). Thinking in action: some characteristics of practical thought. In R. J. Sternberg, & R. K. Wagner (Eds.), *Practical intelligence: nature and origins of competence in the everyday world* (pp. 13 – 30). New York: Cambridge University Press.

Selden, A., & Selden, J. (2005). Perspectives on advanced mathematical thinking. *Mathematical Thinking and Learning, 7*(1), 1-13. doi: 10.1207/s15327833mtl0701_1

Shaffer, D. W. (2006). Epistemic frames for epistemic games. *Computers & Education, 46*(3), 223-234. doi: 10.1016/j.compedu.2005.11.003

Shernoff, D. J., Csikszentmihalyi, M., Schneider, B., & Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly,* 18(2), 158–176. doi: 10.1007/978-94-017-9094-9_24

Sihronen, T. (2011). *Players Unleashed! Modding The Sims and the Culture of Gaming*. Amsterdam: Amsterdam University Press

Sinclair, B. (2010) The Sims turns 10, tops 125 million units. *Gamespot.* Retrieved from: http://www.gamespot.com/articles/the-sims-turns-10-tops-125-million-units/1100-6249485/

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology, 64*(2), 489–528. doi:10.1111/j.1744-6570.2011.01190.x

Spradley, J.P. (1980). *Participant observation.* New York: Holt, Rinehart and Winston.

Squire, K. (2002). Cultural framing of computer/video games. *International Journal of Computer Game Research,* 2(1).

Squire, K. (2004). *Replaying History: Learning World History Through Playing Civilization III*. (Unpublished doctoral dissertation). Indiana University, Indianapolis, IN

Squire, K. (2008). Open-Ended Video Games: A Model for Developing Learning for the Interactive Age. In K. Salen, *The Ecology of Games: Connecting Youth, Games, and Learning*, (pp. 167–198). Cambridge, MA: The MIT Press

Squire, K.D. (2006). From content to context: videogames as designed experience. *Educational Researcher, 35*(8)**,** 19-29. doi: 10.3102/0013189X035008019

Stake, R. (2000). Case studies. In N.K. Denzin & Y.S. Lincoln (Eds), *Handbook of Qualitative Research* (2nd ed*.,* pp. 435-454). London: Sage Publications.

Steinkhler, C. & Squire, K. (2014). Video Games and Learning. In K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences,* (2nd ed., pp. 377-396). New York, NY: Cambridge University Press

Strauss, A. & Corbin, J. (1998) *Basics of qualitative research: techniques and procedures for developing grounded theory*. Thousand Oaks: SAGE.

Stylianides, G. J. (2009). Reasoning-and-proving in school mathematics textbooks. *Mathematical Thinking and Learning, 11*(4), 258-288. doi:10.1080/10986060903253954

Sudmann, J.A., & Stockmann, R. (2008). *Computer games as a sociocultural phenomenon: games without frontiers, war without tears*. Basingstoke: Palgrave Macmillan.

Suits, B. (1978). *The Grasshopper*. Toronto: University of Toronto Press

Suits, B. (2005). *The Grasshopper: Games, Life and Utopia*. Broadview Press

Tall, D. (2002) *Advanced Mathematical Thinking*. Boston: Kluwer

Tanes, Z. & Cemalcilar, Z. (2010). Learning from SimCity: An empirical study of Turkish adolescents. *Journal of Adolescence, 33*(5)**,** 731-739.

Electronic Arts (2010). *The Sims 3* [PC DVD-ROM]. USA: Electronics Arts Inc.

Thornham, H. (2011). *Ethnographies of the videogame: Gender, narrative and praxis*. Ashgate

Tinsley, H. E. A. & Weiss, D. J. (2000). Interrater reliability and agreement. In H. E. A. Tinsley & S. D. Brown (Eds.), *Handbook of Applied Multivariate Statistics and Mathematical Modeling,* (pp. 95-124). San Diego, California: Academic Press.

Tolmie, A.K., Topping, K.J., Christie, D., Donaldson, C., Howe, C., Jessiman, E., Livingston, K. & Thurston, A. (2010). Social effects of collaborative learning in primary schools. *Learning and Instruction, 20*(3)**,** 177-191. doi: 10.1016/j.learninstruc.2009.01.005

Tornqvist, D. (2015). Exploratory Play in Simulation Sandbox Games: A Review of What We Know About Why Players Act Crazy. In IRMA (Vol. 4) *Gamification: Concepts, Methodologies, Tools, and Applications* (pp. 1751-1770). IGI Global

Triantafillou, C., & Potari, D. (2010). Mathematical practices in a technological workplace: the role of tools. *Educational Studies in Mathematics, 74*(3), 275-294. doi: 10.1007/s10649-010-9237-6

Underwood, J. & Underwood, G. (1999). Task effects on co-operative and collaborative learning with computers. In K. Littleton and P. Light (Eds.) *Learning with computers: Analysing productive interactions.* London: Roudledge.

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research, 34*(3), 229–243. doi:10.2190/FLHV-K4WA-WPVQ-H0YM

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Wartofsky, M. (1979). *Models: Representation and the scientific understanding*. Dordrecht, The Netherlands: Reidel

Watson, W.R., Mong. C.J & Harris, C.A. (2011). A case study of the in-class use of a video game for teaching high school history. *Computers & Education. 56*(2), 466-474. doi: 10.1016/j.compedu.2010.09.007

Wegerif, R., & Mercer, N. (1997) Using computer-based text analysis to integrate quantitative and qualitative methods in the investigation of collaborative learning. *Language and Education. 11*(4), 271-286.

Wells, G. (1993). Reevaluating the IRF sequence: A proposal for the articulation of theories of activity and discourse for the analysis of teaching and learning in the classroom. *Linguistics and Education*, *5*(1), 1–37. doi: 10.1016/S0898-5898(05)80001-4

Wendel, V., Gutjahr, M., Battenberg Ph., Ness, R., Fahnenschreiber, Göbel, S. & Steinmetz, R. (2013) Designing a Collaborative Serious Game for Team Building Using Minecraft.In I. C. Vaz de Carvalho & P. Escudeiro (Eds.), *Proceedings of 7th European Conference on Games Based Learning* (pp. 569-578). Reading, UK: Academic Conference and Publishing International Limited

Wernholm, M. & Vigmo, S. (2015) Capturing children's knowledge-making dialogues in Minecraft. *International Journal of Research & Method in Education, 38*(3), 230-246. doi: 10.1080/1743727X.2015.1033392

Wertsch, J. V. (1991). *Voices of the mind*. Cambridge: Harvard University Press.

Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press

Wirman, H. (2011). *Playing The Sims 2: Constructing and Negotiating Woman Computer Game Player Identities through the Practice of Skinning*. (Unpublished doctoral dissertation). University of the West of England, Bristol, UK.

Wirman, H. (2014). Playing by Doing and Players' Localization of The Sims 2. *Television & New Media, 15*(1), 58-67. doi; 10.1177/1527476413505001

Wouters, P., van Nimwegen, C., van Oostendorp, H. & van der Spek, E.D. (2013). A Meta-Analysis of the Cognitive and Motivational Effects of Serious Games. *Journal of Educational Psychology*, *105*(2), 249-265. doi: 10.1037/a0031311

Wright, W. (2003). Forward. In Freeman, D. E., (Ed.) *Creating emotion in games: The craft and art of emotioneering*. USA: New Riders Games

Yin, R.K. (2009). *Case study research: design and methods* (4th edition). Thousand Oaks: Sage

Young, M.F., Slota, S., Cutter, A.B., Jalette, G., Mullin, G., Lai B., Simeoni, Z., Tran, M. & Yukhymenko, M. (2012). Our Princess Is in Another Castle: A Review of Trends in Serious Gaming for Education. *Review of Educational Research, 82*(1), 61-89. doi: 10.3102/0034654312436980

Zinchenko, V. (1995). Cultural-historical psychology and the psychological theory of activity: retrospect and prospect. In J. V. Wertsch, et al. (Eds.), *Sociocultural studies of mind* (pp. 37-55). Cambridge: Cambridge University Press.

Zinchenko, V. P., & Gordon, V. M. (1981). Methodological problems in the psychological analysis of activity. In J. V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 72-133). New York: Sharpe.

Zorn, C., Wingrave, C., Charbonneau, E., and LaViola, J. (2013) Exploring Minecraft as a Conduit for Increasing Interest in Programming. In *Proceedings of the International Conference on the Foundations of Digital Games* (pp. 352-359). New York, NY: ACM

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer, 38*(9), 25-32. doi: 10.1109/MC.2005.297

Appendices

The Appendices chapter consists of four parts:

- **Appendix A** provides the table of Juul's (2003, p.31) game definitions that were summarized earlier in Chapter 2 (Section 2.4.2.1, p. 32).

- **Appendix B** illustrates the Brousseau's puzzle which was used in during the pilot study of this research (see Chapter 3, Section 3.3.2, p. 60).

- **Appendix C** provides the ethics' review documentation which I referred to in Chapter 3 (Section 3.7, p. 86)

- **Appendix D** presents the extracts from players' gameplay and talk that were relevant to the Open Codes and Categories which were shaped during the first stage of analysis (see Chapter 5, Section 5.1.1, p.122).

Appendix A: Game definitions

Table A-1 is adopted from Juul's (2003, p. 31) table of game definitions that he conducted after reviewing several researchers, psychologists, game developers and others' game definitions.

Source	Definition
Johan Huizinga 1950, p.13.	[…] a free activity standing quite consciously outside "ordinary" life as being "not serious", but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner. It promotes the formation of social groupings which tend to surround themselves with secrecy and to stress their difference from the common world by disguise or other means.
Roger Caillois 1961, p.10-11.	[...] an activity which is essentially: Free (voluntary), separate [in time and space], uncertain, unproductive, governed by rules, make-believe.
Bernard Suits 1978, p.34.	To play a game is to engage in activity directed towards bringing about a specific state of affairs, using only means permitted by rules, where the rules prohibit more efficient in favor of less efficient means, and where such rules are accepted just because they make possible such activity.
Avedon & Sutton-Smith 1981, p.7.	At its most elementary level then we can define game as an exercise of voluntary control

	systems in which there is an opposition between forces, confined by a procedure and rules in order to produce a disequilibrial outcome.
Chris Crawford 1981, chapter 2.	I perceive four common factors: representation ["a closed formal system that subjectively represents a subset of reality"], interaction, conflict, and safety ["the results of a game are always less harsh than the situations the game models"].
David Calley 1988, p.50.	A game is a form of recreation constitute by a set of rules that specify an object to be attained and the permissible means to attaining it.
Katie Salen & Eric Zimmerman 2003, p.96.	A game is a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.

Table A-1: Juul's (2003, p.31) table of game definitions

Appendix B: Pilot study, Brousseau's puzzle

Figure B-1 below presents a panoramic view of the initial house that was created by the researcher, in *The Sims 3* game, following Brousseu's puzzle, during the pilot study of this research. The goal was to use the ratio of 7:4 to build a smaller copy of this house as a guest house on top of the original one. Two walls of the guest house had already been created by the researcher and these walls were the starting point.

Figure B-1: Pilot study – Brousseau's puzzle (Initial house)

Table B-1 below presents the dimensions of each shape's sides.

<table>
<tr><th>Shape</th><th>Side 1 (Vertical)</th><th>Side 2 (horizontal)</th><th colspan="3">Side 3</th><th>Height</th></tr>
<tr><td>GREEN</td><td>21</td><td>28</td><td colspan="3">14 (diagonal)</td><td>14</td></tr>
<tr><td>PINK triangle</td><td>21</td><td>21</td><td colspan="3">21 (diagonal)</td><td></td></tr>
<tr><td>Light GREEN</td><td>14</td><td>21</td><td colspan="3">21 (diagonal)</td><td>14</td></tr>
<tr><td>PINK rect.</td><td>21</td><td>7</td><td colspan="3">-</td><td></td></tr>
<tr><td>BLUE</td><td>14</td><td>21</td><td colspan="3">-</td><td></td></tr>
<tr><td>WHITE</td><td>7</td><td>21</td><td>35</td><td>14</td><td>21</td><td>7</td></tr>
<tr><td>YELLOW</td><td>14</td><td>28</td><td colspan="3">14 (diagonal)</td><td>14</td></tr>
<tr><td>TOTAL</td><td>49</td><td>49</td><td colspan="3">-</td><td></td></tr>
</table>

Table B-1: Dimensions of the shapes shown in Figure B-1

Appendix C: Ethics review documentation

Appendix B includes documents that were prepared and given to participants and their parents prior to the data collection process, in order to obtain their written consent to participate in this research. First, the *Participants' assent form* that was given to participants is provided in C.1. Second, the *Participant's legal representative inform consent form* and the *Parents' information sheet*, which were given to participants' are provided in C.2 and C.3 respectively. Lastly, the final Ethics' Committee approval letter is provided in C.4. It is important to note that the title of this PhD thesis that is presented in the documents of this Appendix has changed after the data collection. Nonetheless, I provide the documents in the original form that was given to participants, participants' parents and the Ethics Committee.

C.1. Participants' assent form (translated)

Exploring gameplay of the video game *The Sims 3*

My name is Antri Avraamdou and I am a student in the University of Leeds. I am now doing a project where I am trying to search the way children play video games because a lot of children enjoy playing them. I want to see how children, like you, play *The Sims 3* digital game and if you would like, you can be in my study.

If you decide that you want to be in my study, you will play *The Sims 3* digital game with a friend of yours and you will build houses together on your or your friend's computer. I will be in the same room with you as you play the game in case you need help. I will need to run a software on the computer which will record whatever you do on the screen, because I might forget what you did. Your voices will be recorded as well, so that I can later view and listen to what you and your friend did while playing. I will not record your faces or your hands, just the computer screen and your voices.

If you want to be in my study, you might like the game a lot. But, you might also feel bored. If you do feel bored, you can stop playing the game and it will be OK. If you play the game for my study, you and your friend will need to build houses for Sims families. You and your friend will build a house from scratch, then you will build a house for a family you will choose from the game's library and finally, you will need to change the design of a house that a family already has in the game.

Other people will not know if you are in my study. I will put things I learn about you together with things I learn about other children, so no one can tell what things came from you. When I tell other people about my study, I will not use your name, so no one can tell who I am talking about.

Your parents or guardians have to say it's OK for you to be in the study. After they decide, you get to choose if you want to do it too. If you don't want to be in the study, no one will be mad at you. If you want to be in the study now and change your mind later, that's OK. You can stop at any time and I will delete all the recordings I made.

My telephone number is 99612007. You can call me if you have questions about the study or if you decide you don't want to be in the study any more. I will give you a copy of this form in case you want to ask questions later.

Agreement

I have decided to be in the study even though I know that I don't have to do it. Antri Avraamidou has answered all my questions.

________________________________ __________________

Signature of Study Participant Date

________________________________ __________________

Signature of Researcher Date

C.2. Participant's legal representative inform consent (translated)

Title of Research Project: Exploring gameplay of the commercial video game *The Sims 3 **
Name of Researcher: Antri Avraamidou

Initial the box if you agree with the statement to the left

1) I confirm that I have read and understood the information sheet dated (DATE) explaining the above research project and I have had the opportunity to ask questions about the project. ☐

2) I understand that my child's participation is voluntary and that she/he is free to withdraw at any time without giving any reason and without there being any negative consequences. I acknowledge that in case my child withdraws, his/her data up to the withdrawal date will be deleted. ☐

3) I understand that should my child not wish to answer any particular question or questions, she/he is free to decline. ☐

4) I understand that my child's data will be collected in my house and I give my consent to the researcher to install the above game to my computer or my child's computer. In addition I understand that the researcher will uninstall the game from the computer once the data collection procedure is completed. ☐

5) I understand that my child's data will be kept strictly confidential and her/his data will be treated anonymously. I give permission for members of the research team (researcher and supervisors) to have access to my child's anonymised responses. ☐

6) I understand that my child's name will not be linked with the research materials, and she/he will NOT be identified or identifiable in the report or reports that result from the research. ☐

7) I agree for the data collected from my child to be used in future research ☐

8) I understand the reasons why my child and I must NOT be aware of the exact purpose of the research. I also understand that the researcher will inform me and my child about the research's aims AFTER the data collection. ☐

9) I agree for my child to take part in the above research project under these conditions. ☐

________________________	________________	________________
Participant's legal representative	Date	Signature
________________________	________________	________________
Researcher	Date	Signature

C.3. Parents’ information sheet (translated)

Exploring game play of the video game *The Sims 3**

Dear Parent(s),

You and your child are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please feel free to contact me in **99612007** if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish your child to take part. Thank you for reading this.

Research’s purposes and *The Sims 3* game

I am a PhD student of the School of Education at the University of Leeds (United Kingdom) and this research is conducted for my PhD thesis (estimated submission year: 2014). I wish to investigate children’s game play of a particular video game *The Sims 3* (http://el.thesims3.com/), which is a real-life simulation game, not created for educational purposes. Within this game, players control *The Sims*, which are virtual families, and can edit their houses and other buildings, build new houses or delete others and so on. All video games have a PEGI[8] (Pan European Game Information) label which is an advisory age-group suitability number. *The Sims 3* game is rated at 12+. This means that *The Sims 3* is advised to be played by children 12 years and older, mostly because of some interactions that the fantasy characters of the game might have with each other, when players play this game. However, I wish to specifically investigate children’s game play when building houses in the building mode of this game, where there is no such interaction. Thus, if you agree for your child to participate in this research your child will **only** build houses within the **building mode** of the game. If you need me to demonstrate the game and/or show you what your child will do within this game, **we can arrange a meeting where we can play the game together.**

**Note that this was the initial title of the thesis*

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[8] For more information about PEGI, visit: http://www.pegi.info/en/index/id/24

What will my child do in this project and for how long?

Your child will play the Building mode of *The Sims 3* digital game with another child (a friend of his/her) and both of them will work together to build two houses and edit one. First, they will freely build a house of their choice. Then they will build a house for a specific family with a specific budget, which they will select from the game's inventory. Lastly, they will edit a house originally created by me and which has the following scenario: "*The family of the house is consisted out of three members: the mother, the father and one child. The mother is now pregnant and thus the family's house needs to be adjusted so that the baby will have a room of its own*".

Please note the following:

- **The data collection will take place in either your house or your child's friend's house.** This is essential to the research's aims because the players need to play the game in an informal and friendly setting, which makes them feel comfortable. The video game needs to be installed in your computer (or your child's friend's computer) but will be uninstalled once the data collection ends. *You can install the game yourselves if you want to.*
- **I will need to be present during your child's game play. This is necessary in order to ensure that your child will not play other parts of the game apart from the Building mode and to provide assistance if needed.** In addition, at least one of you must be with me in the house during the data collection.
- **Your child's game-play AND his/her discourse with the other member of the group will be recorded** using a screen recording software (BB FlashBack for Windows and Snapz Pro X for Mac) which will also be installed in your (or your child's friend's computer). This software will also be uninstalled after the data is collected. A USB microphone (provided by me) might also be needed to establish high audio quality. The recording of your child's group game play is essential to this project in order for me to understand your child's group actions and rationales.

- **The duration of the data collection will depend on the time your child's group needs to accomplish the tasks described above and the frequency they meet.** From a pilot study, it is expected that the children will need to meet 5-6 times and each game play should take from 60-90 minutes. Thus, the estimated timeframe is between 1-3 months. **But please note that this timeframe may vary. In addition, you will choose preferred dates and times for the data collection.**
- Your child's group recordings will be played and replayed by me and **sometimes my supervisors** (Professor John Monaghan and Dr Aisha Walker) might need to view your child's group activity as well. However your child's data will be **confidential and treated anonymously**. **Only I will know your child's real name.**

Anonymity and confidentiality

All the information that I collect about your child during the course of the research will be kept **strictly confidential**. Your child's data will be anonymous and your child will not be able to be identified in any reports or publications. A pseudonym will be given to your child and only I will be aware of the association of that pseudonym to your child's real name.

The audio and screen recordings of your child's group activities collected during this research will be used only for analysis and for illustration in conference presentations and/or lectures. Nevertheless, a still image of the computer screen recorded during your child's group activities might be used for illustration in academic journal papers. No other use will be made of them without your written permission, and no one outside the project (me and my supervisors) will be allowed to have access to the original recordings.

All recorded data will be stored in an encrypted location in my laptop and in a University of Leeds password-protected M-drive that only my supervisors and I will have access to.

Participants and right to withdraw

It is up to you to decide whether your child takes part or not in this research project. If you do decide that your child takes part you will be given this information sheet to keep (and be asked to sign a consent form) and **your child can still withdraw at any time** without any consequences or question asked on my behalf. You do not have to give a reason. **All recorded data of your child's group up to the date of withdrawal will be deleted**. Also, if your child's friend withdraws from this project then you and your child will decide whether your child wants to continue playing the game alone. If you decide to withdraw as well, then you have the right to do so, without any consequences.

Whilst there are no immediate benefits for those children participating in the project, it is hoped that this work will enhance your child's skills in designing 3D shapes, like houses and because this game is a very popular game, your child will most likely enjoy playing it. If your child feels bored and does not want to play the game any longer, s/he will have the right to withdraw at any time.

Please contact me within a week if you wish your child to take part in this research project so that I can provide you with the Informed Consent sheet that you must sign.

Contact for further information

Miss Antri Avraamidou
PhD student, School of Education, University of Leeds
Tel: 99-612007 / 22-772066
e-mail: ed07a3a@leeds.ac.uk

Prof. John Monaghan
Main Supervisor
School of Education, University of Leeds
Tel: 0044 113 3434603
e-mail: J.D.Monaghan@education.leeds.ac.uk

Thank you for taking the time to read through the information.

C.4. Ethics' Committee approval letter

Performance, Governance and Operations
Research & Innovation Service
Charles Thackrah Building
101 Clarendon Road
Leeds LS2 9LJ Tel: 0113 343 4873
Email: j.m.blaikie@leeds.ac.uk

UNIVERSITY OF LEEDS

Antri Avraamidou
School of Education
University of Leeds
Leeds, LS2 9JT

AREA Faculty Research Ethics Committee
University of Leeds

13 February 2012

Dear Antri

Title of study: **Exploring mathematical learning through game play of the commercial video game *The Sims 3***

Ethics reference: **AREA 11-082**

I am pleased to inform you that the above research application has been reviewed by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and following receipt of your response to the Committee's initial comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	*Version*	*Date*
AREA 11-082 Antri Avraamidou response to AREA 11-082 provisional opinion.txt	1	23/01/12
AREA 11-082 PEGI Questionnaire.pdf	1	23/01/12
AREA 11-082 Antri Avraamidou RESPONSE to ethical review.docx	1	23/01/12
AREA 11-082 Information Sheet revised.docx	1	23/01/12
AREA 11-082 Parents' consent form revised ENG.docx	1	23/01/12
AREA 11-082 child_assent.doc	1	23/01/12
AREA 11-082 Ethical Review Application form Antri Avraamidou.pdf	1	03/11/11

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval. This includes recruitment methodology and all changes must be ethically approved prior to implementation.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited.

Yours sincerely

Jennifer Blaikie
Senior Research Ethics Administrator
Research & Innovation Service
On behalf of Dr Anthea Hucklesby (Chair,AREA Faculty Research Ethics Committee)

Appendix D: Extracts from open codes and categories

Table D-1 below illustrates extracts of players' gameplay and talk which were coded during the first stage of analysis, where Open Codes and Categories were shaped (see Chapter 5, Section 5.1.1, p. 122).

Categories and Open Codes	
Category 1 – Experiencing the reality of the game	
1.1 Considerations about the virtual characters in *The Sims* (i.e. Sims family)	• **(E&A, House 2)** E: "We should add a library because he (the Sim) likes books" • **(G&N, House 2)** G: "Because then (*if they do not get them sofas*), they will not be able to sit in one place, they will run around the house like crazy. Without any sofas. We need to delete this part (*area, so as to get more money*) and get them sofas to sit" N: "Yes, delete it and then get them (their Sims) in to see what they will do"
1.2 Accessibility and usability of the house	• **(E&A, House 1)** A: "We made a mistake. People are going to enter the house through the toilet room?" E: "What did I just say?" A: "I know what to do" (*deletes a row of the swimming pool so as to create a path for entry points from the living room and the kitchen*) • **(S&K, House 1)** K: "Oops, we forgot something important" S: "What?" K: "Did we create stairs to get to the upper floor?" S: "Oops, kind of important"
1.3 Reference to real-life houses' structure and appearance (culture and everyday experience)	• **(S&K, House 1)** *The girls were creating the dining room of House 1 and Stella suggested to add another table, in a way that guest could see each other (similar to typical table arrangement of Cypriot festive dinners)* S: "Yes. We should turn it (*rotate*) so as to be able to see the others (*guests*)". K: "You mean like this?" S: "Yes, like you did before, with the other table" K: "Like this" (*she rotates the new table and places it in parallel with the other table*)

	S: "Yes. I think it's nice now, don't you? They can see the others (*guests*) as well. K: Yes it's nice now." • **(G&N, House 1)** G: "We are done, finished" N: "What about a dining table?" G: "It's there (*in the kitchen*)" N: "But in my house, we have one" (*George's house has a dining table in the kitchen*) G: "OK, there they are (*in the menu*), you put it then"
1.4 Consideration regarding Sims family's safety and privacy	• **(M&C, House 1)** M: Add a smaller window there (toilet) so that they (neighbours) cannot see us • **(G&N, House 2)** N: "They don't have windows here" G: "Yes we should add windows here so that they can breathe and not die"
Category 2 – Appearance considerations	
2.1 Colour the tiles and the walls of the house	• **(E&A, House 2)** A: "We need to add wallpaper in the living room. Something free and bright" E: "and something that will look good with the wooden tiles" (*the living room's floor*) • **(S&K, House 1)** S: "No, not that one, there are colours. Go back, go back (*K selects desk again*) K: "OK" S: "Put this one, the black one" K: "No, I don't like that one. Should we get the white one that matches the bed instead?" S: "Yes, get the white one"
2.2 "It looks nice"	• **(E&A, House 1)** A: "Wow, that looks perfect!" E: "I like the bedroom, the mirror is nice" • **(S&K, House 1)** K: "It's too dark" S: "Add this one (*K adds it*) Oh this will look very nice" K: "Yes!"
2.3 "It looks ugly", "I don't like it"	• **(S&K, House 2)** K: "This is the worst TV I've ever seen" • **(M&C, House 1)** M: "It's not nice, I don't like the roof, it's ugly" • **(G&N, House 2)** N: "But then, it (*the house*) will not look good"

2.4 Appearance in comparison to other Sims houses	• **(E&A, House 2)** A: This house will be better looking than the previous one we did… just kidding!” E: “Yes, the other one was pretty too but this one is more normal” A: “Yes, it’s cheaper, that’s why it’s more normal” (*they laugh*) • **(G&N, House 2)** G: “Nikos, should we delete it here as well?” N: “Yes, like the house next to this, rectangle” (*they move the camera view to see the neighbour’s house*) G: “That’s a big one, we should delete this part because will not have any money left”
Category 3 – Interaction with the game’s features (options)	
3.1 The walls drop down when working with the room	• **(E&A, House 1)** A: “Where did the wall go?” (they recreate the wall, but it’s still down – they need to click on the “walls-up” button) […] E: “Don’t we have walls behind that?” A: “The walls are there, they are just down, see? (A moves the mouse on the wallpapers at the bottom of those walls) • **(S&K, House 1)** S: “I can’t get the mirror right” (*on the wall*) K: “Get the walls up so that you can see where to place it”
3.2 Issues navigating from one floor to another	• **(E&A, House 1)** When the girls re-entered their house after accidentally exited the building mode of their house, the roof appeared: A: “Is that our house?” E: “How are we going to get inside?” (*Alexia then deletes the roof “to get in”)*
3.3 Read pop-up and menu items	• **(M&C, House 1)** When the group tried to create the foundations of the house next to the pavement: M: “I can’t, what’s wrong?” C: “I don’t know… ’Can’t exceed the limits’… says something like that” M: “What’s this?”
3.4 Errors and feedback / game’s restrictions	- A door needs to be supported by a wall otherwise the game gets the door in red colour **(M&C, House 1)** - While on the 2nd floor, you cannot create tiles on the ground floor **(E&A, House 1)** - An item (i.e.a door) cannot be placed somewhere that will intervene with the space of other items **(S&K, House 1)** - Due to budget constraints, some items of the menu are restricted **(i.e. M&C, House 2)**

3.5 Using night mode and/or grid option to view the grid	• **(E&A, House 1)** E: "Turn on night mode to see the squares" A: "I get confused with those squares… I think that the foundations are larger" … E: "Turn on the night mode to see how much space we have"
Category 4 – Comparison – Area (space) – Size – Arrangement issues	
4.1 Making comparisons (size and/or value)	• **(E&A, House 1)** Once they created the foundations the girls zoomed out E: "Look at the neighbour's house (laugh), ours is small" (they added more foundations) … after finishing the house: E: "Our house is more modern and prettier than the neighbour's house but his house is bigger and normal. Ours is not normal" • **(S&K, House 1)** S: "Are these (*lamps/lights*) the cheapest ones?" K: "These are a bit expensive, they are 95 but they do a really good job (*adds one lamp of* §*95*) but we should use these ones in the other rooms (*shows the lamps that cost* §*45*)"
4.2 Area (space) issues	• **(S&K, House 1)** K: "Yes, excellent! (*talking about the dining room and the living room*). We have some empty space here though" S: "Yes" K: "What are we going to do with this area? We can do a playroom" S: "Let's think about it" • **(M&C, House 1)** C: "What are we going to do with all this?" M: "Which?" C: "All this space… It's huge *(the kitchen size*). Look at the size of the table".
4.3 Arrangement of items and furniture	• **(E&A, House 2)** *The girls wanted to add a couch for the family in the living room* E: "Put it there and turn it so as to face the TV" A: "We can rotate it diagonally" E: "I was just about to suggest the same thing" The girls move and rotate the TV and the couch in several directions until they get it in a place they agreed on. • **(S&K, House 1)** The girls were trying to add stairs to connect the floors but the game showed an error (red colour):

	K: "Maybe it's because of the lights" (*lamps*) S: "Delete them" K: "I think we might need to move the beds and the other things too" S: "Yes, I think we might"
4.4 House structure issues	• **(E&A, House 1)** E: And the door (main entrance) will be in the toilet… A: Be quiet! OK, let's add a door now… Oh! We made a mistake! People will enter the toilet to enter the house? (sounds disappointed) E: What did I say? A: I know what to do (and deletes rows of swimming pool so as to create a path for the living room entry and a kitchen entry) E: The swimming pool will be in parts now. […] A: "Can we move the house?"
Category 5 – Ways to save money / spend less	
5. Ways to save money / spend less	• **(E&A, House 2)** A: "We need a bathroom… we'll have some space between the bedroom and the bathroom (hallway)" E: "No, we should have the bathroom and the bedroom attached. We won't need to create extra doors" • **(S&K, House 2)** K: "Not there, in the kitchen, we should break a wall instead of adding a door" S: "Oh, OK!" K: "There" (she deletes two columns of walls) S: "Nice, now there is light coming in. Nice" K: "More money" • **(M&C, House 2)** C: "We are left with little (money)" M: "That's why I am saying not to add too many winodws… 1, 2,…10, 11 windows!" C: "We haven't added many" M: "We should only leave a window per room" C: "No" M: "We have lamps, why do we need so many windows?" C: "To get air!" M: "OK. Then fewer per room" • **(G&N, House 2)** G: "We should make the house smaller *(deletes foundations*) so it will not be expensive" N: "OK" G: "See? We get money back"

Category 6 – View rotation and/or zoom	
6. View rotation and/or zoom	• **(E&A, House 1)** The girls used the camera rotation, angle and/or zoom so as to view their house's appearance and in instances where they had trouble viewing: A: "Could it be that we've created a ceiling?" E: "Move down (*the camera*)" (*Alexia changes the angle of the camera*). Yes, that's a ceiling" • **(S&K, House 2)** S: "Move the walls down to see what it looks like" (K rotates the view) K: "This is how someone will see our kitchen and at night (switch to night view) and further (zooms out)" S: "Nice. They will see the sink first. We should add a table and chairs in front"
Category 7 – Emotions when referring to budget issues	
7. Emotions when referring to budget issues	• **(E&A, House 2)** E: "Oh my God! Look how much we are left with" A: "And we haven't done anything yet" • **(M&C, House 2)** C: "Everything is red (restricted because there was not enough money)" M: "Where are they going to go when they will want to go to the toilet? We need to get more (money)"
Category 8 – Players' interaction with each other	
8.1 Disagreements between players regarding their choices	• **(M&C, House 1)** They are trying to create a swimming pool and experiment with the curved ones: M: "Why don't we remove this (the curved part) and add a straight one (rectangular shape)? To get a good swimming pool?" C: "No! Leave it as it is, we don't need to" • **(G&N, House 1)** N: "Add this one (*toilet*)" G: "No, not that one. This one (*shows other*) and we should put it here" N: "And one more here" G: "No, not there, here" (*shows else place*)
8.2 Explanation of choices / suggestions	• **(S&K, House 2)** S: "Without walls" (to separate the dining room from the rest of the living room) K: "What?"

	S: "It doesn't need walls" K: "But it does" S: "Do we have walls downstairs?" (real house) K: "True, we don't have either in my house" S: "So why did you add walls?" K: "We don't need walls you are right" (deletes the walls)
Category 9 – Players' interaction with the researcher	
9.1. Questions towards the researcher	• **(M&C, House 1)** They are trying to create the swimming pool but the game keeps showing an error (because there is a tree obstructing the area): C: "Move it up, left, move it further" M: "It can't, why?" (asking the researcher) AA: "It says that there is something obstructing the area. Maybe there is a tree in that area" M: "Right!" • **(S&K, House 2)** S: "In order to get the room brighter do we need to add more lights?" AA: "What do you think?" K: "Maybe lights, windows…" AA: "Try it and see"
9.2. Tips and clues from the researcher	• **(M&C, House 2)** AA: "I don't know if you have noticed but when you delete something, a foundation or a wall, the game refunds you but not with the entire amount" M: "What?" C: "It steals from us?" (This tip was given to all groups)

Table D-1: Open codes and categories –Extracts of players' gameplay and talk