DEVELOPMENT OF DESIGN HEURISTICS FOR DIGITAL EDUCATIONAL GAMES FOR SCHOOL CHILDREN OF 7 TO 11 YEARS OLD

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Abstract

To design a digital educational game (DEG) for children aged 7-11, it is necessary to know which game features are powerful for motivating them to play and learn. In the Pilot Study of my research project, playability heuristics of the GameFlow model were employed as an analytic tool. The heuristics, which were translated into a set of understandable statements for children, were useful for identifying preferable as well as less preferable game features. Based on the reviews of relevant theoretical frameworks from psychology, pedagogy and design, gaps of the GameFlow model were analysed. This led to the development of a set of eight design heuristics named DEG-7-11 v1.

The heuristics were then applied to guide the creation of two new DEGs: FoodGroups-A following all the eight heuristics whereas FoodGroups-B following only two of them. To verify the hypotheses that FoodGroups-A was more educationally effective and enjoyable than FoodGroups-B, the Main Study involving two methods was conducted. For the first method, 182 participating children were randomly assigned to play FoodGroups-A or FoodGroups-B on an individual basis. By comparing the results of pre-tests and post-tests, the educational effect of FoodGroups-A was found to be higher than that of FoodGroups-B. Similarly, based on the results of the validated questionnaire KidsGEQ and the child-friendly statements derived from the GameFlow model, the experiential value of FoodGroups-A was perceived to be higher than that of FoodGroups-B. For the second method, the participating children were asked to rate their agreement with a set of child-friendly statements converted from the heuristics of DEG-7-11 v1, and the children agreed with most of them. The method of producing a child-friendly version of design heuristics originally meant for professional users was shown to be an alternative useful evaluation approach.

Furthermore, Heuristic Evaluation was also employed to evaluate fifteen existing DEGs. The results implied that if game designers considered DEG-7-11 v1 in designing DEGs, the games could have a higher level of user acceptance. Finally, the wording of some DEG-7-11 v1 heuristics was modified to improve their understandability, resulting in DEG-7-11 v2.

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Dedications

I dedicate this thesis to my parents, brother, husband, my family and all of my friends for their great support all the way!

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Abbreviations

2D	Two Dimensional
DEG-7-11	Digital Educational Games for children aged 7-11 years
DEG-7-11 v1	The first version of the DEG-7-11
DEG-7-11 v2	The second version of the DEG-7-11
DEGs	Digital Educational Games
H	Values of the Kruskal-Wallis test
HCI	Human-Computer Interaction
HE	Heuristic evaluation
ISO	International Organization for Standardization
KidsGEQ	Kids Game Experience Questionnaire
N	Number of participants
n_A	The sample size of FoodGroups-A
n_B	The sample size of FoodGroups-B
OS	Operating System
p	Significance Level
PH	Playability Heuristics
RO	Research Objective
RQ	Research Question
Std.	Standard deviation
U	Values of the Mann-Whitney U test
UCD	User-centered Design
UIM	usability inspection method
UX	User Experience
W	Values of the Wilcoxon Signed Ranks Test

Chapter 1: Introduction

This chapter starts with Section 1.1 explaining the background of this research project. It presents the size of the DEG market and its relative importance for the age group of 7-11 years old children, as well as the relevance of DEGs in the education sector, especially their potential for teaching the important topic on nutrition and food groups specified in the National Curriculum for Key Stage 2 pupils (i.e., children of 7 to 11 years old). In addition, the limitations of the existing games on this topic and the need of guidelines for designing robust DEGs, which are simultaneously enjoyable and educationally effective for children aged 7-11 years, are discussed.

An overview of all research aims and objectives is presented in Section 1.2. In Section 1.3 'Research Questions and Research Approaches' the research questions and the planned research approaches are described. The Introduction is completed with Section 1.4 where the main contributions are outlined.

1.1 Background

Ambient Insight, an integrity-based market research firm and Ofcom, the independent regulator for the UK communications industries, published market research reports on the growth rates of game-based learning market for young children (AmbientInsight, 2016; Ofcom, 2015). Playing computer and video games on a daily basis is popular among children aged 5-11 years old, especially there has been an increase on the percentage of playing games among children aged 8-11 years old from 2014 to now and this trend is predicted to continue up to 2019. The most recent reports in 2015 and 2016 of the information about the DEG market including the amount of money/investment involved is detailed in Section 2.2 - Chapter 2. It shows that this is a growing market for the usage of DEGs for children aged 7-11 years.

Computer games are deemed effective to use as an engaging approach to deepen children's understanding of a topic at school. However, quite often children regard digital educational games (DEGs) as unattractive due to various reasons, for example, the games are not sufficiently challenging or do not match their skill levels, the content delivered is difficult to follow, and the visual design is dull (Squire, 2005).

It is worrisome that the number of food-related health problems is increasing among children. As food consumption habits are formed at an early age, children will likely consume various foods later in their life if they acquire knowledge about different food groups and associated nutrients when they are young (Llargues et al., 2011). In the UK, the topic of nutrition is specified in the National Curriculum for Key Stage 2 pupils (DepartmentforEducation, 2014). Children are taught some basic information about food and nutrition at schools. Some research suggests that apart from formal education in schools and responsibility of parents, there should be interventions for preventing childhood obesity and the risks or comorbidities associated (Pietrobelli, Espinoza, & De Cristofaro, 2008). Utilizing computer games to educate children about nutrition has been considered a viable intervention (BritishNutritionFoundation, 2011a; NationalDairyCouncil, 2011; Playnormous, 2011a). Such games can lead to the increase of knowledge of foods and nutrition, contributing to attitudinal and behavioural changes, which are long-term effects that basically cannot be evaluated within a short lifetime of a PhD study. Hence, my research project focused on evaluating the change in knowledge of a specific topic under foods and nutrition, namely food groups.

At present, DEGs are increasingly used as learning tools for children to learn different subjects. Nonetheless, there are only a handful of DEGs focusing on foods and nutrition, for example, ‘Make a Balanced Plate’ (BritishNutritionFoundation, 2011a), ‘Combo Kitchen’ (NationalDairyCouncil, 2011), ‘Brain-Gain’ (Playnormous, 2011a), ‘Pyramid Pile Up Plus’ (Playnormous, 2011b), and ‘Nutrix’ (Alimentarium, 2014). These games have limitations, for example, one of the games is one-level game, which is not sufficiently challenging, and one of those has lot of pressure such as time constrain, speedy objects which is not relaxing for children.

Thus, I was motivated to develop a new DEG on the topic of food groups. Children aged between 7 and 11 years were chosen as the target group, because the size of the DEG market and its relative importance for the age group of 7-11 years old, and the topic of nutrition is covered in Key Stage 2 curriculum. Designing DEGs for children is not an easy task since a designer has to carefully balance playful elements with pedagogical concerns. I aimed to tackle the challenge of designing and developing games that are simultaneously enjoyable and educationally effective for children aged 7-11 years. However, there is a lack of heuristics or guidelines for designing a DEG for this specific age group. Therefore, the main goal of my research project is to develop

and validate a set of design heuristics for DEGs to be played by children aged 7 to 11 years. The main research question is: *Could a set of usable heuristics be developed that would assist designers to create more effective casual digital educational games for children aged 7 – 11*? The second question is: *Could heuristics intended for adult use be adapted so that children could use them to evaluate DEGs*?

1.2 Research aims and Objectives

The main aim of this study is to provide validated design heuristics for more effective design of DEGs for children aged 7-11. A set of empirical studies with their Research Objective (RO) were conducted to accomplish the main aim.

1) **RO1:** To identify which game features are powerful for motivating children aged 7-11 years to play and for enabling them to learn. The detail is in Chapter 4: Pilot Study.
2) **RO2:** To develop a set of validated design heuristics for DEGs for children aged 7-11 years. The detail is in Chapter 5: Developing Design Heuristics.
3) **RO3:** To design and develop new DEGs by integrating and augmenting the preferable features identified and by following the design heuristics (DEG-7-11 v1). The detail is in Chapter 6: Games Design.
4) **RO4:** To provide a set of validated heuristics for designing DEGs for children aged 7-11 years.
    - **RO4.1:** by comparing the educational and experiential values of the two DEGs developed based on different design heuristics (detailed in Chapter 7, Section 7.2.3 7.2.4, 7.2.8, 7.2.9, and 7.2.13).
    - **RO4.2:** by translating the heuristics in the form of child-friendly statements for a questionnaire, which was conducted with children of this specific age range (detailed in Chapter 7, Section 7.2.20).
    - **RO4.3:** by using DEG-7-11 v1 to evaluate DEGs for various domains (detailed in Chapter 8).

1.3 Research Questions and Research Approaches

This PhD research project consists of a set of empirical studies; each study draws on specific methods, tools and techniques. Here is the list of research questions and the planned approaches – the research studies are described in the following sections.

1.3.1 Pilot Study (Chapter 4)

To design digital educational games (DEGs) for children that are both enjoyable and educationally effective is challenging. In this study how Playability Heuristics (PH) has been used as a design tool for a DEG on nutrition is reported. The criteria of PH were translated into a set of statements understandable for children and compiled them into a questionnaire, which was integrated with four existing web-based DEGs on food groups to create an online tool. It was used in a Pilot Study with 100 school children to identify which game features they perceived most preferable. Such features were synthesized to create two new DEGs (see Chapter 6), which were then compared in terms of their experiential and educational values (see Chapter 7). A robust game reference model on DEGs is the ultimate goal of my work.

RQ1: Which game features are powerful for motivating children aged 7-11 years to play and for enabling them to learn?

1.3.2 Developing Design Heuristics (Chapter 5)

Based on the analytic and empirical work completed, besides the preferable as well as less preferable game features were identified, an important implication drawn from the Pilot Study (Chapter 4) was that there is a lack of design heuristics for DEGs for specific age-group of children aged 7-11 years. PH are specific heuristics, including Desurvire and Wiberg (2009), Federoff (2002), Malone (1982), and Pinelle, Wong and Stach (2008) for evaluating the usability of a game design as well as the experiential aspect of gameplay. However, the PH are typically used for evaluating rather than designing games. Also, they focus on evaluating entertainment games rather than educational games. Moreover, none of the existing PH focuses on designing DEGs for school children. Hence, the challenge to bridge this gap by developing a new set of heuristics was assumed. The development of the design heuristics has been grounded

empirically in the Pilot Study (Khanana & Law, 2013) and in the systematic literature review in psychology, pedagogy and design.

RQ2: What are design heuristics for DEGs for children aged 7-11 years?

1.3.3 Game Design (Chapter 6)

Consequently, a set of the eight heuristics known as DEG-7-11 v1 have been developed to address the gaps thus identified. The goal of this study was to develop new DEGs by integrating the preferable as well as less preferable features, which were extracted from the four games on foods and nutrition selected for the Pilot Study. This approach is in line with the recommendations of some previous research studies, based on the idea of applying the Gestalt theory to interaction design (e.g. Dooley & Tuovinen, 2002); the whole is greater than the sum of individual parts when they are integrated seamlessly and effectively. Importantly, the DEGs were designed by applying the heuristics of DEG-7-11 v1 as guidelines. My assumption is that when a DEG is designed by following all of the DEG-7-11 v1 heuristics, it can sustain children's motivation and interest to play and have a positive impact on knowledge gain. I implemented such a game and called it *FoodGroups-A*. In order to verify the assumed benefits of DEG-7-11 v1, another game called *FoodGroups-B* was developed to compare. This game comprised some features contrasting to their counterparts of FoodGroups-A and designed by following only the first two heuristics of DEG-7-11 v1.

RQ3: How can the design heuristics of DEG-7-11 v1 be translated into the actual game design?

1.3.4 Main Study: Validation of DEG-7-11 v1 (Chapter 7)

1.3.4.1 Method 1: Validation of DEG-7-11 v1 by Evaluating Two Game Prototypes

In order to verify the assumed benefits of DEG-7-11 v1, the two games (Chapter 6) were evaluated. It could provide evidence by showing how a DEG comprising all specific features informed by DEG-7-11 v1 (i.e., FoodGroups-A) performs as opposed to the one using some those features (i.e., FoodGroups-B). Hence, for Method 1A, the effectiveness of the game was validated by comparing the children's knowledge on food groups before and after playing the games. The assumption is that FoodGroups-A can result in more effective learning than FoodGroups-B.

Furthermore, Method 1B was so designed as to compare between the two games in terms of gameplay experience, which are hypothesized to be perceived more favourable for FoodGroups-A than FoodGroups-B. In this project study, two tools were used to measure gameplay experience.

In summary, the first method contains three types of assessment: Method 1A: Validation of the educational value of the games with pre- and post-knowledge tests; Method 1B-Measure1: Gameplay experience measured by KidsGEQ; Method 1B-Measure2: Gameplay experience measured by the child-friendly statements derived from the GameFlow model.

RQ4.1: Are there any significant differences in knowledge and gameplay experience, on food groups between two groups of children aged 7-11 years who played one of the two games independently?

1.3.4.2 Method 2: Validation of DEG-7-11 v1 by Children Rating

Apart from validating heuristics by evaluating two game prototypes as described in the previous study, a method of having children rated the heuristics was attempted. DEG-7-11 v1 heuristics were converted into a set of statements, and then presented to children aged 7-11 years, who were asked to rate their agreement with each statement. It was assumed that if the children agreed on the child-friendly statements derived from DEG-7-11 v1, the heuristics would then be viable for designing DEGs that are useful and enjoyable for them.

RQ4.2: To what extent do children aged 7-11 years agree with each of the eight statements derived from DEG-7-11 v1?

1.3.5 Evaluation of Existing DEGs using DEG-7-11 v1 (Chapter 8)

DEGs have increased gradually in popularity over the last few years. Market statistics such as game reviews, or game ratings, are generally used for judging the popularity of games. Why some games are more popular to children than other games? What features make the games successful?

Two significant characteristics of a DEG are enjoyability and educational effectiveness. In designing such a game, a designer should address certain features contributing to these characteristics. In this research study, I identified such features and

converted them in a form of a set of heuristics called DEG-7-11, which can be used for creating DEGs and for evaluating such games.

To prove that the proposed features can affect the popularity of DEGs, fifteen DEGs were selected to be analysed with DEG-7-11 v1. If there is a relationship between the market statistics and the heuristics of DEG-7-11 v1, it can be assumed that the proposed features have the ability to create positive and engaging experience for users. This method can lend further support to the claim about the effectiveness of DEG-7-11 v1.

RQ4.3: Is there any significant relationship between children's preference ratings and the extent to which the DEG-7-11 v1 heuristics is followed?

1.4 Contributions

Summing up, the contributions of my PhD research project are listed as follows:

1) Development of a new set of DEG design heuristics named DEG-7-11 based on the game features empirically identified (Chapter 4) and on the theoretical frameworks systematically analysed (Chapter 5).
2) Design and development of two new DEGs on food groups by integrating the preferable as well as less preferable game features empirically identified with the DEG-7-11 heuristics (Chapter 6).
3) Creation of a child-friendly version of design heuristics by deriving simple statements from the adapted GameFlow model. The statements were used by children to evaluate the game features (Chapter 4 and Chapter 7). Specifically, a child-friendly version of DEG-7-11 was also created as an instrument for evaluating DEGs. (Chapter 7).

Chapter 2: Literature Review

This chapter describes the theoretical frameworks that contribute to the development of DEG-7-11 v1. The key question is how to design enjoyable and educationally effective DEGs for children aged 7-11 years. To answer the question, the first critical step is to ground the heuristics in theories.

Literature Review starts by describing the background of this research project, including the important of DEGs for children learning, the scope and usage of DEGs for children of aged 7-11 which shows the continuous growth of the market, the problem about the awareness of the related knowledge of nutrition and the potential of DEGs as a promising approach to enhance children's understanding of the topic. The examples showing how DEGs are poorly or inadequately designed were given. How heuristics for fun, for learning, for gameplay, for playability are shown. The design heuristics currently available to designers of DEGs for children and some gaps that might be filled by my work are studied. The literature on how heuristics developed is captured and my methods for developing heuristics and design guidelines that are aimed to be robust and being able to stand scrutiny are proposed.

2.1 Digital Educational Game

It is true that many interactive technologies have been used to develop education system such as conversational counseling dialogue, simulated environment, play-based occupational therapy, or games. Hsiao (2007) stated that different fields, such as media design, literature, computer science, education and theatre studies, have used digital games as learning tools. Computer games can be powerful learning environments because the activities embedded therein can help players develop a number of cognitive skills (Robertson & Howells, 2008). Computer games if designed for educating rather than for entertainment purposes are widely known as *serious games*. Many definitions of serious games have been proposed by different researchers in different domains. For the domain of education, the example of Sørensen and Meyer (2007), "Serious Games are defined as digital games and equipment with an agenda of educational design and beyond entertainment." *Digital Educational Game (DEG)* is another term used to describe a serious game for educating students.

2.2 The children DEGs market and usage

In this sub-section, some statistics of the children DEGs market, which are drawn from the firm Ambient Insight, are first reported. It is then followed by a summary of the recent findings of Ofcom concerning the usage of DEGs by children.

2.2.1 The children DEGs market

Ambient Insight (AmbientInsight, 2016), an international integrity-based market research firm that uses predictive analytics to identify revenue opportunities for global learning technology suppliers, has published a market research report on the growth rates of digital learning products and trends in the worldwide game-based learning market. In 2014, worldwide incomes for edugames (mobile and non-mobile combined) gained $1.8 million. The five-year compound annual growth rate (CAGR) is a vigorous 21.9% and incomes will powerfully forward to $4.9 billion by 2019. The worldwide Game-based Learning (GBL) incomes are most intense in Asia, followed by North America.

Game-based learning is pervasive in the early academic grades; Ambient Insight separates the early academic grades segment into three sub-segments: preschool, primary, and secondary. The growth rates in the preschool and primary sub-segments are 28.3% and 21.3%, respectively. There are a very small number of educational games targeting secondary sub-segments. All games used in those sub-segments focus on early childhood learning topics including literacy, numeracy, and basic cognitive skills. Early childhood learning apps occupy the top selling app rankings in China. Eighteen of the twenty top-selling educational apps in Apple's store in China in June 2015 were early childhood learning apps. Basically all early learning childhood apps are game-based.

The growth rate for edugames in Western Europe is a vigorous 26.9% and incomes will be above threefold to $46.2 million by 2019. The United Kingdom is the maximal edugame purchasing country in Western Europe, followed by Spain and France. In the Apple store in the UK in June 2015, nine of the top twenty bestselling educational apps were early childhood learning apps. There were three brain trainers in the top twenty: Lumosity (ranked in third place), Peak, and Fit Brains. In the Windows store in July 2015, eight of the top twenty were early childhood learning apps. In the Amazon store in July 2015, eleven of the top twenty bestselling educational apps were early childhood learning apps including a MY LITTLE PONY app at the first place.

Lumosity's brain trainer occupied the second place.

Over the last five years, investor interest in Game-based Learning firms has been increasing. In 2011, $32.5 million of investment went to Game-based Learning firms, above double the $12.6 million invested in edugame firms in 2010. Game-based Learning suppliers across the world retained $106.3 million in funding in 2014, the highest total in the history of the digital edugame industry. A surprising $83.6 million was invested in edugame supplies in just the first half of 2015 alone.

Investors are investing heavily in suppliers that make edugames for children. Brazil-based Movile's mobile education division called PlayKids reached $15 million in June 2015. PlayKids constantly rank in the top bestselling educational apps in app stores across the world. A Beijing-based firm called Satech develops edugames for children with special needs and reached $10 million in January 2015. A math edugame firm in South Korea named LocoMotive Labs retained $4 million in February 2015. Investors are also interested in firms that sell brain training products: Lumos Labs (Lumosity) has retained $67.4 million in private equity since 2008, Berlin-based NeuroNation reached $2 million in late 2013, Berlin-based Memorado raised $3.3 million in March 2015, on top of the $1.3 million they reached in 2014, London-based Peak reached $7 million in April 2015.

2.2.2 Children's usage of digital games

The data of the above children DEGs market analysis are consistent with the findings presented in the research report entitled 'Children and Parents: Media Use and Attitudes report' (Ofcom, 2015), which is designed to give an accessible overview of media use, attitudes and understanding among children and young people aged 5-15 years old. The analysis sourced from a quantitative survey conducted in November 2015 shows that there has been an increase among younger children in playing games on the Internet, increasing from 30% in 2014 to 37% for 5-7 years old, more than half of all 8-11 years old (52%) have played games on the Internet since 2014. The approximate weekly hours spent gaming on the Internet increases with the age of the children (6.9 hours for 5-7 years old, 9.2 hours for 8-11 years old and 12.2 hours for 12-15 years old). There has been no change in the approximate time spent in gaming by each of the age groups since 2014. It is more likely for children aged 8-11 (12%) or 12-15 (13%) than for 5-7 years old (6%) to use educational games.

Based on the information about the children DEG market and on the Ofcom analysis, there seems a growing demand for DEGs, especially for children aged 7-11 years. As most of the DEGs focus on mathematics and brain training for general cognitive skills, there seems a lack of quality DEGs on food and nutrition that can match well with the topics covered by school curricula, which I describe more in the subsequent section.

2.3 Topics on food and nutrition taught to Key Stage 2 students

In the era of economic and technological competition, the dietary habit of people has changed. People tend to eat more fast food in order to spend more time in their work (Fraser & Edwards, 2010). Parents who are responsible for providing food to their children rely on fast food rather than prepare quality food themselves. Fast food causes an imbalance of basic nutrients in body and thus illnesses. Unbalanced nutrition problem can occur in any stage of life. It is worrisome that the number of food-related health problems is increasing among children.

World Health Organization (2000) reported that regarding the prevention and treatment, people not only rely on technical approaches or specific medical treatments but also on the improved awareness of the related knowledge of nutrition. Both dieticians and teachers have their important roles in children's nutrition in terms of supervising food preparation, planning meals, and nutrition education (Francis, Nichols, & Dalrymple, 2010). Llargues et al. (2011) argued that food consumption habits are formed at an early age and that if children are acquainted with different food types, they will likely get into the habit of consuming a variety of food later on in their life.

There are various efforts to educate children about proper nutrition in order to prevent childhood obesity or related diseases caused by unbalanced nutrition (Pietrobelli, et al., 2008). In the UK, the topic of nutrition is specified in the National Curriculum with the first level being taught at schools at Key Stage 2 and 3 (7 - 11 years old pupils).

While children are taught some basic information about food and nutrition at schools, it is considered more effective to deepen their understanding of this topic through an engaging approach. Some research suggests that apart from formal education in school and responsibility of parents, there should be alternative interventions for mitigating the issue of childhood obesity. In today's digital era, children are generally

familiar with computers which they often use for entertainment. Hence, computer games are regarded as a promising intervention for educating children about food and nutrition.

2.4 Inadequately designed Digital Educational Game

DEGs influence the way how children learn educational content. Properly designed DEGs have the ability to motivate children to learn and to enhance their learning performance. The existing DEGs have different strengths (e.g., a single game suits different genders who have different preferences) and weaknesses (e.g., some games are not sufficiently challenging because of the lack of challenging levels, some are not relaxing for children while playing because of excessive pressures such as time constraint and fast moving objects. Thus, it does not mean that every DEG can succeed in delivering content as well as enjoyment. The following literature reviews give some examples of learning problems due to the inadequately designed DEGs.

Gredler (2004) gave some examples of problems due to the lack of well-designed games and their relation to learning. The first example is the use of graphics which may be distracting, such as the graphics following a wrong answer are more interesting than the graphics following a right answer. It may mislead the learner to enter incorrect responses. Another problem is games are zero-sum exercises. In zero-sum games, only one player wins, while others are not recognized as winners although they may demonstrate considerable learning. It is the educational problem. In an educational setting, winning should be defined as the goal of the game, such as the player would be a winner if she or he could reach a certain criterion or a certain number of points.

Dondlinger (2007) reviewed the publications focusing on educational video games design, tracing to identify elements of game design that support learning. He distinguished the difference of educational games and edutainment games. One of the characteristics that differentiates educational and edutainment is that educational games mainly require strategizing, hypothesis testing, or problem-solving with higher-order thinking rather than rote memorization or simple comprehension. In contrast, edutainment games follow a skill-and-drill format in which players either practice repetitive skills or rehearse memorized facts. However, such characteristics of skill-and-drill have demonstrated gains in learning. In an educational games setting, strategies of skill-and-drill format such as using hints or reminders to recall information from

memory should be incorporated.

All publications find that motivation to play is a significant characteristic of educational games. Motivation leads to the activation of efficient cognitive strategies for long-term memory issues like monitoring, elaborating or organizing information. Educational games that fail to address the issue of motivation can have negative results on memorization and personal development (Dondlinger, 2007). Thus, DEGs should include a system of rewards which motivate players to create deep learning.

In general, designing games is more complex than designing other media, because it needs a careful balance between fun and challenge to ensure its playability. Thus, game developers should understand which game features are important or preferable and which techniques should be included in DEGs in order to motivate children to attain positive learning outcomes.

2.5 User experience and Playability Heuristics

When digital games are developed, the main objective is they have to be fun. It seems that the games should have to be evaluated before launching to players. It appears that there are many issues to be considered in order to make proper designed games. The proper or great interaction design is complex and difficult to define. However, successful interaction design will lead to quality *user experiences (UX)*.

Alben (1996) defines user experience is all the views of how people use an interactive product, how they sense about it while it being used. Law and colleagues (2009) also found that the defining characteristics of UX as derived from the results of their survey were somewhat in line with the ISO definition. The international standard on ergonomics of human system interaction, ISO 9241-210 (ISO9241-210:2010) defines user experience (UX) as “person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service. User experience includes all the users' emotions, beliefs, preferences, perceptions, physical and psychological responses, behaviours and accomplishments that occur before, during and after use.” User experience refers to an overall indication of how people have felt a time to encounter a system (Roto, Law, Vermeeren, & Hoonhout, 2011). Going beyond usability that focuses on instrumental goals, UX research put emphasis on experiential goals.

There are many evaluation methods that focus on finding out how users feel about the system that need to be evaluated. Descriptions of a variety of methods have been reported by researchers and professionals in the field of HCI[1] (Roto, et al., 2011). Heuristic evaluation (HE) is one of those. It is a usability inspection method (UIM) where evaluators use usability principles, called heuristics, for inspecting a user interface. Several inspection reports from a set of evaluators who conduct the evaluation independently are formed to the list of usability problems. HE is cheap and easy to motivate people to do. It does not require advance planning and can be used early in the development process (Nielsen & Molich, 1990; Nielsen, 1994).

Among HE, a method suitable for interaction design evaluation and especially applicable for games is *Playability Heuristics (PH)*. Roto et al. (2012) state that PH is used for evaluating the playability features within games, exposing usability problems and revealing the experiential aspects of gameplay. PH is typically applied for expert evaluation of a game, especially in the early development stage. It is also a relatively cheap and fast method. Therefore, to evaluate DEGs in this research project, among a plethora of UX methods, PH are deemed useful for identifying usability problems and for understanding the experiential aspect of gameplay.

Several sets of PH have been developed. In 2002, Järvinen, Heliö, and Mäyrä (2002) informed design practices and product development with their study, which aimed to discern the necessary elements used to design engaging, fun, and meaningful experiences. In the same year, Federoff (2002) stated that a game would not be sold in the marketplace if it was not fun to play. So, the game design process required considerable care and the use of formal usability evaluation procedures could be better guaranteed by game developers to ensure the satisfaction of game players. Federoff (2002), based on the assumption that heuristics can provide a clear understanding of game design principles, developed a set of game-specific heuristics for evaluating fun. In 2004, Desurvire, Caplan, and Toth (2004) applied their approach - Heuristic Evaluation for Playability (HEP) - to facilitate game design from the user's point of view. HEP is a comprehensive set of heuristics for playability. It is helpful in early game design. However, games designers should rely on users testing since their behavior is unpredictable. Once games designers observe the player's behavior, they can have the specific knowledge necessary to resolve the design problems. To complement the

[1] www.allaboutux.org

existing set, Korhonen and Koivisto (2006) developed a set of playability heuristics specifically for evaluating mobile games. They stated that the user interface was critical for a good gaming experience. Also, the game design itself had a great effect on the gaming experience. Their playability heuristics can be utilized with an expert evaluation method to recognize probable playability problems in the user interface and game design in the early phase of a game project. These heuristics cover general usability, mobility, and gameplay issues of the game. This method is aimed at pre-production and production phases of a game project. In 2008, Pinelle et al. (2008) stated that if a game fails to be designed to have usable interface, it would not create magnetic experience for users and cause to the success of the game eventually. In order to carry out usability inspections of video games, they introduced another set of heuristics for identifying usability problems in early and functional game prototypes.

While different heuristics focus on different aspects of game design, a consolidated set could be useful. Sweetser and Wyeth (2005) integrated different heuristics into a concise and validated model known as GameFlow model, which is structured by the flow theory (Csikszentmihalyi, 1990) and can be used to design, evaluate and understand enjoyment in games. The model comprises a set of elements and associated criteria that can be used to design and evaluate games (Chapter 4; Table 4.1).

2.6 The design heuristics for DEGs for children

In the field of game design for children, some research studies have suggested criteria for designing quality serious games in the domain of education. Malone (1982) discussed why computer games were so captivating. He designed some guidelines for designing for the enjoyability of a game. He conducted three empirical studies to find out what people liked about the games, and used the results to help him design highly motivating instructional environments. It can also have important implications for designing other user interfaces. SEEM is a method for predicting usability and fun problems in games (Baauw, Bekker, & Barendregt, 2005). It can be applied for evaluating products without involving real users as well as applied early to evaluate prototypes of products when it is in the design process. SEEM's checklist consists of questions based on Norman's theory-of-action model complemented with questions based on Malone' s concepts of fun, Challenge, Curiosity and Fantasy. Peterson and

associates (2008) proposed design criteria for educational and edutainment computer games, based on a comprehensive review of the body of research concerning the developmental and educational value of computer games for children, focused on children aged 12 and under. The six categories of design criteria are: curiosity, fantasy and player control; challenge; socialization; pedagogy; technology; special-needs of young children. Sánchez et al. (2009) proposed the *Facets of Playability* to study properties of each attribute in order to identify the elements necessary to achieve overall *Playability* in different video games and to minimise any unanticipated or negative results, thereby ensuring a high quality of playability and improving the *Player Experience* in the final product. Tan and colleagues (2011) developed a game, Socialdrome®, a learning environment for enhancing social skills of primary school children aged between 9 and 12. They presented a game design framework for child-centered interaction called CALSIUM. This framework composes a set of parameters that are worthy to consider in planning a child-centered game design. It consists of seven components: Creativity, Activities, Learnability, Storylines, Interactivity, Usability, and Multimodality.

2.7 Gaps of existing heuristics

Although the research studies mentioned above proposed criteria for evaluating and designing quality digital games, not many specific heuristics exist for designing. Those heuristics are intended for evaluating games, and not specifically for design purposes. The existing heuristics focus on entertainment games, not DEGs. The heuristics have been developed not specifically for children's computer games. These existing guidelines developed by many researchers are similar; this is a drawback because of possible overlapping criteria. Another issue is that most guidelines are heuristic-based, they are abstract, e.g. 'games must have an objective or goal' (detailed in Chapter 5; Section 5.3.2.2), they do not specify any preferable game features or gaming techniques for sustaining children's motivation to play. This makes those guidelines hard to use for designing specific game features.

Given the gaps of existing design guidelines reviewed above, I decided to develop a set of heuristics for designing DEGs for children.

2.8 Developing existing heuristics and design guidelines

To construct a predictive method called Structured Expert Evaluation Method (SEEM) (Baauw, et al., 2005), a pilot study was conducted to test the assumption that it would be possible for adults to predict problems that children could encounter in computer games by using and without using a standard predictive method. The results could show a requirement for a new proper predictive method. Then, appropriate theoretical basis was employed for the construction of the new predictive method, for example, Norman's theory-of-action and Malone's fun concept allowed a systematic analysis to construct a guideline for supporting user product interaction.

Peterson et al. (2008) had a comprehensive literature review of the body of research concerning the developmental and educational value of computer gaming for children. Based on the review, design criteria are proposed for educational and edutainment computer games. It proposed that DEGs should be designed to bring up all of the criteria.

It was useful for this research study to apply the method proposed by Baauw, et al. (2005) for deriving an alternative set of heuristics by conducting a pilot study to acquire the requirement together with reviewing the appropriate theories to ground the construction of the heuristics. It could be argued that the method proposed by Peterson, et al. (2008) could obtain only single requirement; it relied on only the idea of experts but not be proved by further empirical study.

However, rather than acquiring the requirement from experts which are adults, this research study instead gathered opinions from children, who are the real users. It can be discussed that the process of deriving a new set of heuristics of this research study relied on two sources of information, including the experts' opinion from a comprehensive literature review and the children's opinion from the empirical study.

2.9 Summary

Children play a lot of DEGs and they are often rather poorly designed, there is a shortage of guidelines for DEGs and there are few DEGs developed with input from children. The later chapter shows the development of an alternative set of design guideline which assumed to be robust and stands scrutiny for DEGs designers.

Chapter 3: Overall Methodology

This PhD research project consists of five studies. While all of them are grounded in the User-centred Design (UCD) philosophy, each study draws on specific methods, tools and techniques. Section 3.1 illustrates an overview of the research project. Section 3.2 describes the methodology for the Pilot Study, as the initial step to identify preferable as well as less preferable game features. Section 3.3 describes the methodology for the development of the set of design heuristics called DEG-7-11 v1. Section 3.4 describes the methodology for game design, as it aimed to create two versions of digital educational games on food groups which were developed by applying DEG-7-11 v1 differently for guiding the design. Section 3.5 describes the methodology for the Main Study: validation of DEG-7-11 v1. Section 3.6 describes an alternative methodology for validating DEG-7-11 v1 by evaluating of existing DEGs using DEG-7-11 v1. Furthermore, Section 3.7 mentions about the qualitative approaches used in this research study. Also, Section 3.8 describes the steps of the ethics approval of this research study.

3.1 Overview

An overview of the research project is illustrated as Figure 3.1.

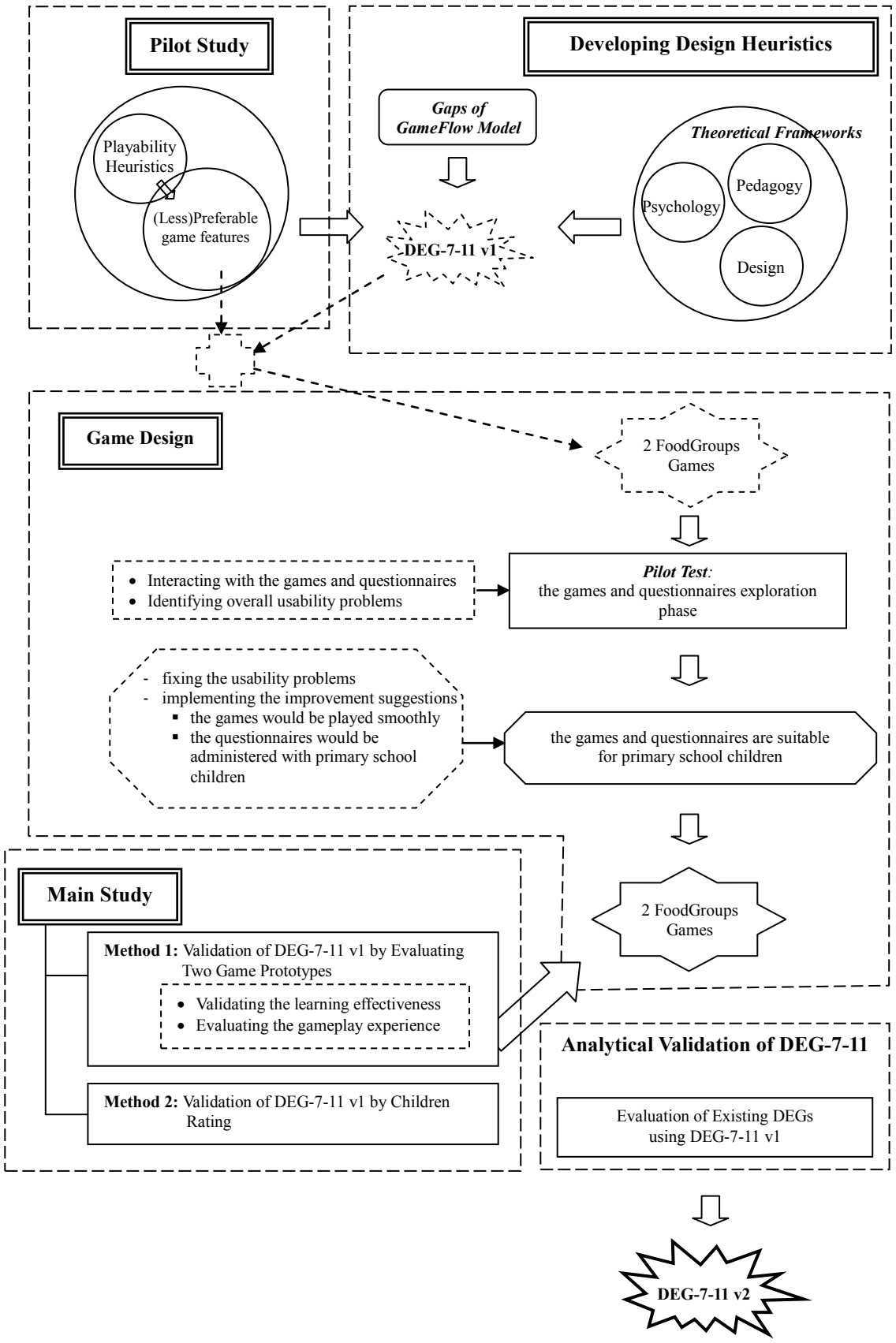


Figure 3.1 The research project process

3.2 Pilot Study

A goal of the Pilot Study was to identify what game features could be effective to enable children aged 7-11 years old to learn with fun. To accomplish it, the following research question was answered and methodology was applied.

RQ1: Which game features are powerful for motivating children aged 7-11 years to play and for enabling them to learn?

3.2.1 Methodology

The criteria of the GameFlow model were translated into a set of simple statements that children would be able to comprehend and were contextualized with specific games. All the statements derived were compiled into a questionnaire, which was integrated with the existing four games into an online tool. The preferable as well as less preferable features of the four games (see Chapter 4) were identified. Children aged 7 to 11 years were asked to play and evaluate all the four games on an individual basis. Besides, the children were asked to describe their likes, dislikes and improvement suggestions of the games. Observations were conducted when the children were playing the games and informal interviews afterwards.

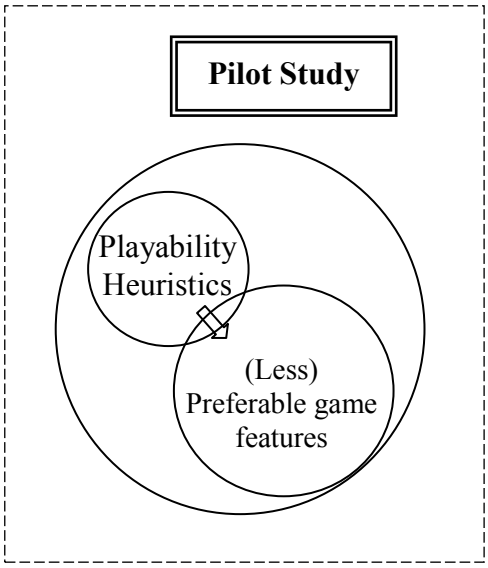


Figure 3.2 The process of identifying the preferable as well as less preferable game features

3.3 Developing Design Heuristics

A goal for this study is to develop a set of design heuristics for DEGs for school children of 7 to 11 years old. Several steps are needed to take into account while developing the design heuristics. In the following text, research question and methodology were presented.

RQ2: What are design heuristics for DEGs for children aged 7-11 years?

3.3.1 Methodology

For developing an alternative set of DEG design heuristics for children aged 7-11 years, the preferable and less preferable game features, as evaluated by the children in the Pilot Study, were extracted and synthesized into the eight heuristics. They were further substantiated by theoretical frameworks from three disciplines – psychology, pedagogy, and design, and were compared to the GameFlow model (Sweetser & Wyeth, 2005) with the aim of addressing the gaps (Figure 3.3). The resulting set of the first version of heuristics was denoted as DEG-7-11 v1. The set of the eight heuristics was then validated with the target group. It is assumed that if the design of an educational game is informed by DEG-7-11 v1, then the game will enable primary school children to learn the topic addressed by the game effectively and with fun.

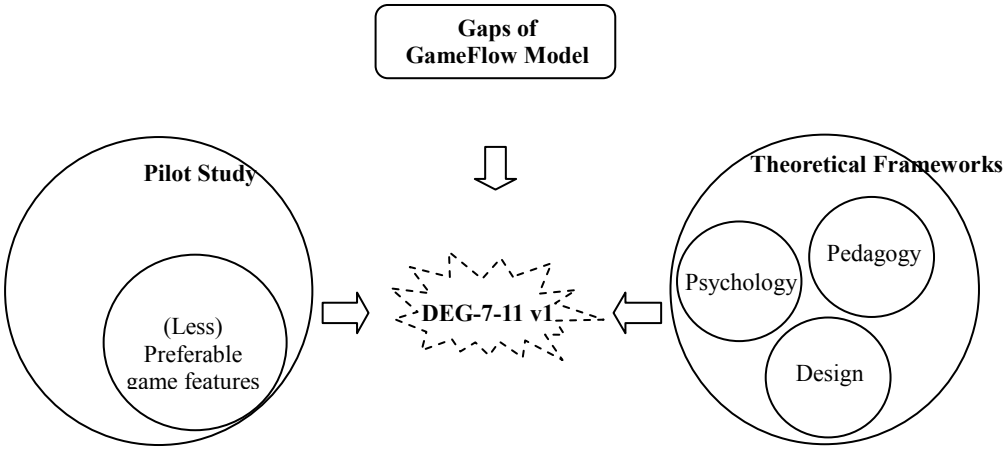


Figure 3.3 The process of deriving DEG-7-11 v1

3.4 Game Design

Two versions of DEGs were developed. *FoodGroups-A* was designed by following all the eight heuristics of DEG-7-11 v1, whereas *FoodGroups-B* followed only the essential heuristics. This section describes research question and methodology of game design.

RQ3: How can the design heuristics of DEG-7-11 v1 be translated into the actual game design?

3.4.1 Methodology

As mentioned earlier, the empirical findings of the Pilot Study informed the design of the two game prototypes on food groups based on the preferable as well as less preferable features identified in the existing four games and on DEG-7-11 v1 (Figure 3.4). FoodGroups-A was aimed to have the more preferable features from the four selected games and was designed using all the eight heuristics of DEG-7-11 v1, whereas FoodGroups-B was aimed to have contrasting (less preferable) features and was designed by only two essential heuristics of DEG-7-11 v1. After that, the Pilot Test was conducted to evaluate the overall usability of the games and the understandability of the questionnaires aimed to assess children's perception of the games as well as the learning efficacy of the games. Observations and interviews were also used to collect empirical data.

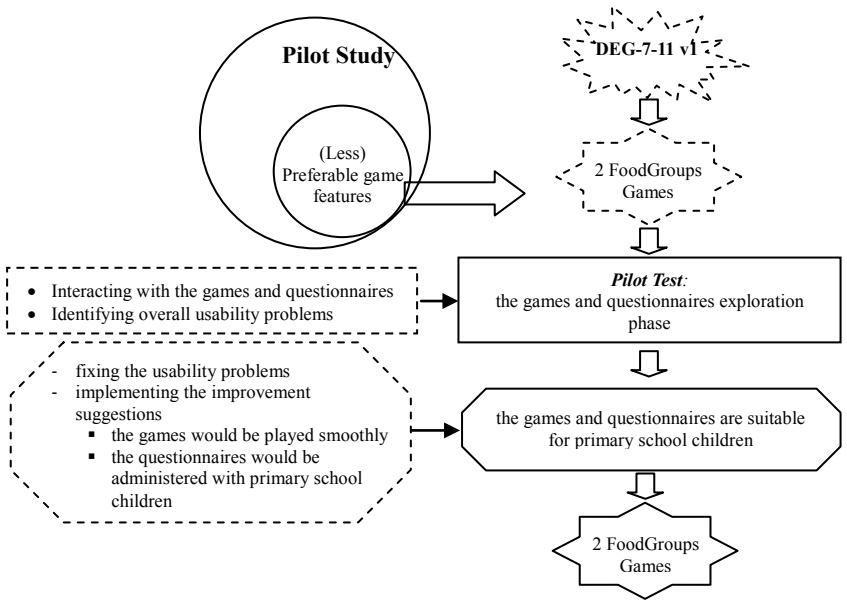


Figure 3.4 The process of implementing and primary validating the DEG-7-11 v1 for game design

3.5 Main Study: Validation of DEG-7-11 v1

The DEG-7-11 v1 heuristics were validated with children aged 7-11 years. Main Study consists of two methods. The first method was set to evaluate the final versions of the two FoodGroups game prototypes (Chapter 6). The educational value of the two games was compared. Moreover, gameplay experience of these games were measured and compared by two tools, by KidsGEQ and by the child-friendly statements derived from the GameFlow model.

While such validation data alone are not sufficient for making a solid conclusion about the effectiveness of DEG-7-11 v1, the second method is a validation approach where children's agreements on the child-friendly statements derived from DEG-7-11 v1 heuristics were evaluated by children aged 7-11 years. The validation studies are illustrated in Figure 3.5.

3.5.1 Method 1: Validation of DEG-7-11 v1 by Evaluating Two Game Prototypes

The assumed benefits of DEG-7-11 v1 were verified by conducting an empirical study to compare the educational value and gameplay experience of the two games. Results of the study could reveal how specific game features as informed by DEG-7-11 v1 would benefit the children. The first method contains three types of assessment: Method 1A: Validation of the educational value of the games; Method 1B-Measure1: Gameplay experience measured by KidsGEQ; Method 1B-Measure2: Gameplay experience measured by the child-friendly statements derived from the GameFlow model.

RQ4.1: Are there any significant differences in knowledge and gameplay experience, on food groups between two groups of children aged 7-11 years who played one of the two games independently?

3.5.1.1 Methodology

This study covered both the evaluation of gameplay experience and validation of learning efficacy of the games.

After fixing the usability problems and improving the questionnaires based on the Pilot Test, the two games were then validated through a series of methods. As the two games were designed differently but with essentially the same content, a between-subjects design was adopted to avoid the carryover effects. While conducting the games evaluations, questionnaires, observations and informal interviews approaches were employed to collect both behavioural and attitudinal data. I was presenting in the computer lab or classroom where the children were playing the games to observe and code the children' behaviours.

3.5.2 Method 2: Validation of DEG-7-11 v1 by Children Rating

The ultimate goal of this study is to empirically validate DEG-7-11 v1. Children's opinions can confirm the agreement of the proposed heuristics.

RQ4.2: To what extent do children aged 7-11 years agree with each of the eight statements derived from DEG-7-11 v1?

3.5.2.1 Methodology

An empirical study was conducted to validate DEG-7-11 v1. Each heuristic was first transformed into a statement understandable to school children of that age bracket. The statements were digitalized as an online questionnaire to which 182 children responded. They were implemented as part of the pre-game-play tests. The children were instructed to indicate to which extent they would agree on each statement with a five-point Likert scale (1: 'strongly disagreed'; 2: 'disagreed'; 3: 'neither disagreed nor agreed'; 4: 'agreed'; 5 'strongly agreed'). Results were aimed to show that DEG-7-11 v1 heuristics were theoretically and empirically well-grounded.

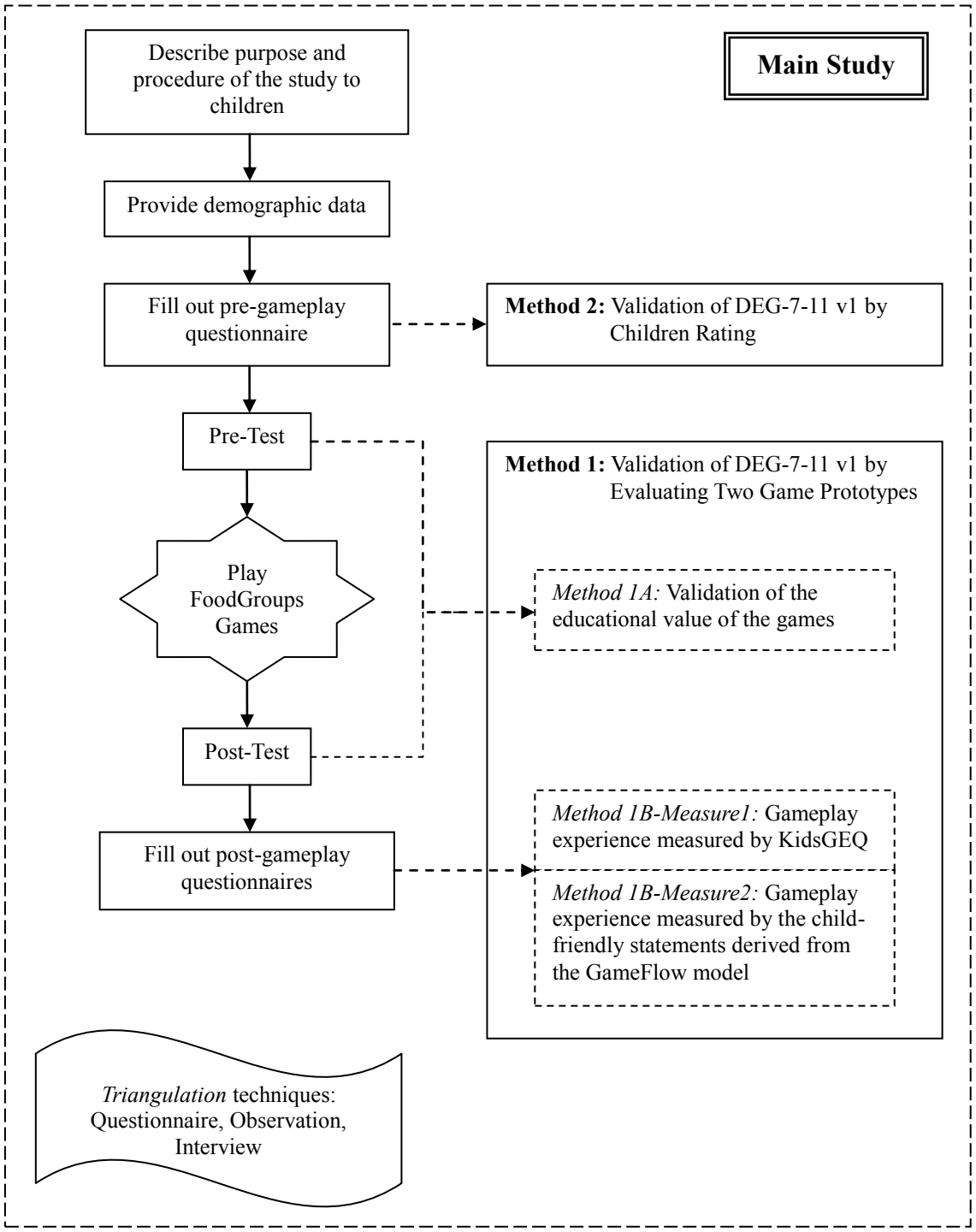


Figure 3.5 The process of Main Study: Validation of DEG-7-11 v1

3.6 Evaluation of Existing DEGs using DEG-7-11 v1

DEG-7-11 v1 heuristics was adapted to analyse the existing DEGs of different domains (Chapter 8).

RQ4.3: Is there any significant relationship between children's preference ratings and the extent to which the DEG-7-11 v1 heuristics is followed?

3.6.1 Methodology

Fifteen DEGs were selected based on the same category, and platform. All are educational games which are run on Windows OS. However, domain contents of those games were chosen randomly, not specific on only food and nutrition such as math, English, and history.

I applied the heuristics of DEG-7-11 v1 to evaluate these 15 DEGs. The percentage of DEG-7-11 v1 heuristics followed by each game was calculated and correlated with the user rating statistics obtained from the website named Learn4Good[2]. Learn4Good is one of top web destinations for education resources in the U.S., Canada, UK, Europe, the Middle East and globally. It began in 2003 and has received over 25 million visitors a year since 2007. The user rating statistics supplied me with a chance to study preferable features in a large number of games.

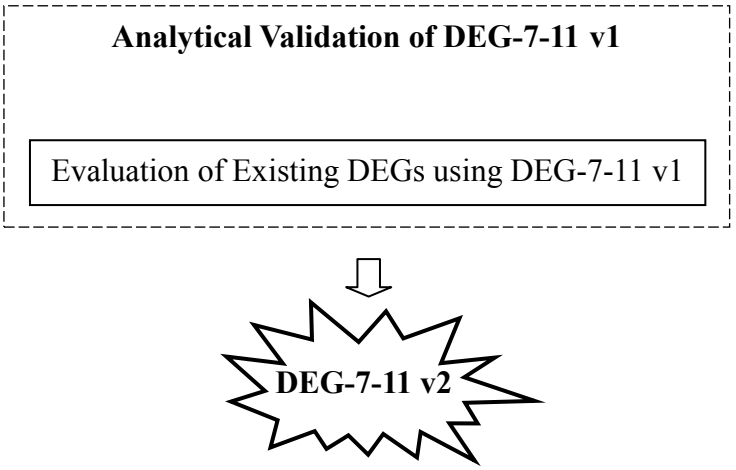


Figure 3.6 The process of Evaluation of Existing DEGs using DEG-7-11 v1

[2] http://www.learn4good.com/games

3.7 Qualitative Approaches: Observations and Interviews

To measure the two FoodGroups game as mentioned above, the measurement instruments are in the form of questionnaire. Apart from that, Hart, Sutcliffe, and Angeli (2013) suggested that observation and semi-structured interview could be used to obtain deeper insights into users' experience as well as usability of games. Thus, based on the related literature, I developed the observation coding scheme and the interview protocol and pilot tested them with four children. Codes in the observation scheme, and questions in the interview protocol were then modified based on the evaluation feedback. Unfortunately, in the Main Study, due to different constraints, there were only a few opportunities to conduct observations or interviews. The data collected were too limited to allow any systematic analysis. Nevertheless, the descriptions of both methods are included in Appendix A and Appendix B.

3.8 Ethics Approval

When a research project contains related activities which involve human participants, ethical issues are required to be approved through the University of Leicester's ethical review system and must be completed before approaching participants to take part in the research study.

To design a DEG to meet children's needs, they were involved either the requirement analysis or evaluation process. The children acted as either co-designers or evaluators in the context of this research study. Gathering and storing their personal data must be under the ethical approval.

3.8.1 Steps of Ethics Approval

The ethic approval procedures consisted of the following steps:

- All sections of an online application form must be completed. The progress of the application was able to be tracked using the review system.
- Once the application was submitted, it was assigned to the relevant Ethics Sub-Committee. A reviewer from the Sub-Committee considered the application.

- The reviewer would either approve it or request revisions. In my case, revisions were needed before approving. I carried out the revisions and resubmitted again through the online system for several times. It took around three months to complete the process (March – May 2015).

3.8.2 Ethical issues

Particular ethical issues and the plan to address these issues must be provided in the application. I provide some main issues as following:

3.8.2.1 General issues

- Ensuring compliance with legal requirements related to working with children within the UK and in other jurisdictions, researcher must obtain the Criminal Record Bureau check.
- No image of young people would be obtained.
- No tangible reward of any kind would be given as a result of participating in the study.
- The issue of Internet access while they were responding to the survey, children would be reminded of the safety of using any websites with indecent or inappropriate content. Teachers and parents would be advised to monitor the children.
- All participations of children are entirely voluntary. Informed consent forms and letter for both pupils and parents should be provided, especially the description of what to do with the data collected, how to store the data and how long to keep it. The consent form should not be over-complicated, particularly for children 7 years old.

3.8.2.2 Content issues

- The content of the proposed game should be summarised in the application form for the ethics approval.
- Any possible adverse impact the study may have upon the children at a later date and how to address should be explained. For example, diet can clearly impact people adversely. There probably should be some recognition of

eating disorders such as anorexia nervosa and consideration of whether or not this research might contribute to this. To the age groups that might be affected and consider how game might or might not contribute to such an eating disorder, either in a negative or positive way. If there will be adverse impacts, what potential adverse impacts, and steps of taking to minimise/address such issues needed to be explained.

The researcher was aware of the risks although it was very low. All the aforementioned issues were thoroughly discussed with the thesis supervisor. The strategies of addressing the issues were planned.

Chapter 4: Pilot Study

This chapter illustrates how to use PH as a design tool to identify game features which are powerful for motivating children aged 7-11 years to play and to learn.

4.1 Background

To design DEGs that are simultaneously entertaining and educationally effective is challenging (Rankin, McNeal, Shute, & Gooch, 2008) as it involves a delicate balance between learning and playing. Hence, to design a DEG it is necessary to know which game features are powerful for motivating children to play. The approach proposed for identifying such game features is adopting and adapting *playability heuristics* (PH) as an *empirical* tool to elicit user requirements.

4.1.1 Adaptation of Playability Heuristics

According to Markopoulos et al. (2008), an activity aiming to provide feedback and guidance to interaction design is *evaluation*, which can provide seeds of concepts for new versions of existing products or entirely new products. In other words, evaluation results can provide designers and developers a set of directions and ideas to follow for designing or redesigning games.

Markopoulos et al. (2008) also confirmed that, a heuristic evaluation (HE) plays an important role in game design. It is used for inspecting the usability of interface design, as Nielsen (1994) specified. Heuristics for evaluating the playability features of games are called *Playability Heuristics (PH)*. Various PH have been proposed as mentioned in Section 2.5, for example, Malone (1982) designed guidelines for designing the enjoyability of a computer game. Järvinen, et al. (2002) informed necessary elements used to design engaging, fun, and meaningful product. Federoff (2002) developed a set of game-specific heuristics for evaluating fun. Desurvire, et al. (2004) proposed a comprehensive set of heuristics for playability - Heuristic Evaluation for Playability (HEP) - to facilitate game design from the user's point of view to resolve the design problems. Pinelle et al. (2008) introduced a set of heuristics for identifying usability problems of video games.

However, the traditional way of using playability heuristics is usually used by experts as evaluators to find usability problems in games. It is true that the set of usability principles or heuristics have come from experts' recommendations on preferable features which can motivate players to play through games. Some of the preferable features have been formulated into checklists as an integral part of usability inspection methods.

In acknowledging the evaluative role of PH, this study aims to look at the important role of children as end-users and also the more important role of PH in design process. In addition to using PH for identifying potential usability problems, PH can be used for analysing the preferable design in game. It can be argued that the principles for revealing problems and the guidelines for designing are two sides of the same coin. Moreover, if game designers develop games by referring to the checklist of evaluation, those games can elicit quality user experience. Therefore, this study aimed to adapt a set of usability principles, which are normally used for exposing problems, as principles for designing.

4.1.2 Children as evaluators and contributors for game design

In order to know which game features are preferable for children, DEG designers and developers should design games that can meet children's needs and preferences. Children, as end users of DEGs, should be involved in game design. According to Markopoulos et al. (2008), the needs of non-technical experts and non-professional users should be addressed in the design of a system. This approach aims to improve usability and user experience, to create products or services that satisfy users and fulfill their enjoyable experiences.

Based on the assumption that children can contribute their own ideas to creative design (Druin, 1999), they are involved as informants, testers, end-users and cooperative inquirer throughout the entire design process (Tan, et al., 2011). Children are enabled to develop a narrative version of a game before it is implemented digitally (Duh, Yee, Gu, & Chen, 2010) and to evaluate and redesign game prototypes iteratively with the game design and development team (Markopoulos, et al., 2008).

According to Scaife and Rogers (1998), the *informant-based approach* is an alternative model with sources of information coming from children, who are involved throughout the design process. Before designing, children are consulted. During and after designing, they also requested to test prototypes, provide feedback, and evaluate

output design. In addition, Druin (1999) involved children throughout the design process as partners, it is called *cooperative inquiry*. Children can contribute their own ideas for creative design. Markopoulos et al. (2008) also mention that the design process of interactive products is normally complicated and that the approach *User-centered Design (UCD)* should be adopted. The approach implies capturing requirements at the early stage, ongoing user involvement for refining design concepts throughout the system development cycle till user-based evaluation of the final product. User-based information collected and analysed with the UCD approach from the potential users helps evaluate and redesign an interactive system such as games. Mazzone, Xu, and Read (2007) claimed that with UCD, users are included into the whole product cycle from concepts generation to product prototyping, evaluation and implementation, whereas in traditional approaches users are included mostly at the end of product cycle to evaluate and validate the product.

Duh et al. (2010) suggested the approach of asking children to develop their own narratives version of the game before developing the digital version. They mentioned that in the process of designing games for children, children were traditionally treated as testers, who solely gave feedback on prototypes for developers. They argued their proposed approach could incorporate children's input into the design process more effectively than the traditional approach. Another approach for designing children's game was proposed by Tan et al. (2011). 10-year old children were involved as informants, design partners, testers, and users. Children are involved in building game prototype, designing game, redesigning game, and evaluating game.

The several studies above advocate that involving children is highly supportive for the process of interactive product design in every session of product cycle. As I aimed to design a DEG to meet children's preferences and contain with preferable features for them, children were involved as evaluators in the session of getting requirement and evaluating the DEG of this research project.

4.2 Research study

The contribution of the Pilot Study was aimed to identify the preferable as well as less preferable game features of the existing games. This research study aimed to adapt the concept of evaluating by using playability heuristics as part of game design approach.

4.2.1 Apparatus

4.2.1.1 GameFlow: A Model for Evaluating Player Enjoyment in Games

Many game design heuristics have been proposed by different researchers, and some common elements can be identified. From a comprehensive review of the literature on playability heuristics, the *GameFlow model* (Sweetser & Wyeth, 2005) was chosen as the framework. Sweetser and Wyeth (2005) studied different heuristics in the literature such as Desurvire's (2004) and Federoff's (2002), and then they tried to synthesize and integrate the game design heuristics into a well-structured model of enjoyment in games. They also employed flow theory (Csikszentmihalyi, 1990), which provides a general model that summarizes the concepts common to all experiencing enjoyment, as a structural foundation for synthesizing and organizing the heuristics into a concise model. The GameFlow model includes eight heuristics which have an overall goal and a set of central criteria that can be used to design and evaluate games with respect to player enjoyment. The GameFlow heuristics and criteria are summarized in Table 4.1.

Given its comprehensibility, the GameFlow framework was adopted in my research project to design and evaluate a game on educating children on nutrition.

Table 4.1 Elements of the GameFlow model (Sweetser & Wyeth, 2005)

Element	Definition	Criteria
Concentration	Games should require concentration and the player should be able to concentrate on the game	To be enjoyable, a game has to require concentration. Games can captivate players' concentration by providing stimuli that are worth attending to. Stimuli are always in multiple forms (e.g., sound, animation, graphics, and speech). Games should be visually appealing, with interesting character models.

Element	Definition	Criteria
Challenge	Games should be sufficiently challenging and match the player's skill level	Games should provide different levels of challenge. The levels of challenge increase as the players progresses through the games and increase their skill level. They should provide new challenges at an appropriate pace.
Player Skills	Games must support player skill development and mastery	Players should have adequate information to start playing game. Players should be taught how to play the games. The way players are taught to play the game is crucial to their skills development and enjoyment of the game.
Control	Players should feel a sense of control over their actions in the game	Players should feel a sense of control over their characters in the game world. The player should be able to customise the controls and the gameplay to fit their learning and playing styles or the game should be designed to allow different styles of learning and playing. For players to become emotionally immersed in the world, they need to be given options for what they can be, do and have in the game.
Clear Goals	Games should provide the player with clear goals at appropriate times	Games must have an object or goal. It should be provided early or at appropriate times though an introductory part to define the background story of the game. To achieve flow, the goals must be clear. It should be brief to describe a mission.
Feedback	Players must receive appropriate feedback at appropriate times	Games need to provide frequent in-game feedback for players to determine distance and progress towards objectives. Positive feedback should be given to encourage mastery of the game. Games should reward players with feedback on progress and success. Also, when they lose they should get feedback about if and how they are moving in the right direction.

Element	Definition	Criteria
Immersion	Players should experience deep but effortless involvement in the game	Players should feel emotionally involved in the game. Games should transport the player into a level of personal involvement emotionally and viscerally. People play games to calm down after a hard day or to escape from everyday worries.
Social Interaction	Games should support and create opportunities for social interaction	-

4.2.1.2 Translating the GameFlow Criteria into Statements

Generally, a set of usability heuristics can serve both as a checklist for identifying problems and as guidelines for designing an interactive system such as games. Following such guidelines will likely result in positive user experiences. However, as usability heuristics are normally deployed by HCI professionals, the words used are probably not understandable for average children aged 7-11 years old (the target group of my research project). Furthermore, heuristics and associated criteria are generic. Hence, it is necessary to translate the criteria specified in the GameFlow model into a set of simple statements that children would be able to comprehend and to contextualize the criteria for specific games.

In achieving so, the first step was to identify which criteria of each element of PH could be mapped to specific game features to be analysed. For instance, a criterion of 'Challenge element' says "the *level of challenge* should increase as the player progresses through the game and increases their skill level", the wording "*level of challenge*" were mapped to the feature of "game level" (detailed in Table 4.2). Then, a statement was derived from the overall meaning of criterion selected and incorporated with the specific feature wording, eventually the derived statement is "The way that the game moves on from an easier to a harder level helps me remember the food groups.". Note that there is not always one-to-one correspondence between criterion and statement. Similar criteria associated with the same element are translated into a single statement (e.g. the element of 'control' in Table 4.2). Conversely, one criterion can be

translated into more than one statement (e.g. the element of 'concentration' in Table 4.2). Consequently, there were different numbers of statements per element (Table 4.3). Eventually, a set of criteria could be derived to 12 statements which were used for evaluating across the four games (S1 – S12), while another set of criteria were derived to 16 statements used for evaluating specific features of the individual four games (S13xx - S16xx). However, there is no statement for the element of 'social interaction' because the DEG to be created in my study is a single-player game. All of derived statements from the GameFlow model (Sweetser & Wyeth, 2005) are displayed in Table 4.2. Altogether 28 statements were developed for the seven elements Table 4.3) and compiled into a questionnaire, which was integrated into an online tool called *Tell Us about the Games*[3], of which the instructional page is shown as Figure 4.1.

Figure 4.1 The instructional page of the questionnaire "Tell Us about the Games"

[3] www.cs.le.ac.uk/people/kk207/tellus.html

Table 4.2 All of derived statements from the GameFlow model

Element	Criteria	reduced GameFlow statements
Concentration	- games should provide a lot of stimuli from different sources	S1: I like the graphics/pictures which are clear and meaningful. S2: I like the colours used in the game. S3: My eyes are comfortable because the text size is easy to read. S4: I understand the choice of words easily. S10: I like the animation effects (e.g. speed, timing). S11: I like the sound effect (e.g. background, performance feedback).
	- games must provide stimuli that are worth attending to - games should quickly grab the players' attention and maintain their focus throughout the game - players shouldn't be burdened with tasks that don't feel important - games should have a high workload, while still being appropriate for the players' perceptual, cognitive, and memory limits - players should not be distracted from tasks that they want or need to concentrate on	S12: I like the way the game presents the information about food and nutrition.
Challenge	- challenges in games must match the players' skill levels	S15Co: I can move to the other levels if I can accomplish the previous ones.
	- games should provide different levels of challenge for different players	S16Br: The way that the game has more than one level and different situations makes me curious.
	- the level of challenge should increase as the player progresses through the game and increases their skill level - games should provide new challenges at an appropriate pace	S15Py: The way that the game moves on from an easier to a harder level helps me remember the food groups.

Element	Criteria	reduced GameFlow statements
Player Skills	- games should include online help so players don't need to exit the game	S5: The instructions on playing the game are nice.
	- game interfaces and mechanics should be easy to learn and use	S6: It's easy to understand how to play the game.
	- players should be able to start playing the game without reading the manual	S14Br: I can play the game without reading the instructions.
	- learning the game should not be boring, but be part of the fun - players should be taught to play the game through tutorials or initial levels that feel like playing the game	S13Bal: I like playing the game without reading, just seeing the pictures.
	- games should increase the players' skills at an appropriate pace as they progress through the game - players should be rewarded appropriately for their effort and skill development	S14Py: I like obstacles (Chompies). I try to get rid of them from each level.
Control	- players should feel a sense of control over the game interface and input devices	S9: I feel good because it is easy to play, just click, drag and drop.
	- players should feel a sense of control over their characters or units and their movements and interactions in the game world - players should feel a sense of control over the game shell (starting, stopping, saving, etc.)	S13Br: I like to play quiz games. S14Bal: It is just a simple game. I can play it in a short time. S13Py: It is a problem solving game. I like to think when playing.
	- players should feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world) - players should feel a sense of control over the actions that they take and the strategies that they use and that they are free to play the game the way that they want (not simply discovering actions and strategies	S16Co: I like having the chance to make my own recipe for a combination of foods.

Element	Criteria	reduced GameFlow statements
	planned by the game developers) - players should not be able to make errors that are detrimental to the game and should be supported in recovering from errors	
Clear Goals	- overriding goals should be clear and presented early - intermediate goals should be clear and presented at appropriate times	S13Co: I can tell which ingredients are in combination foods.
Feedback	- players should receive feedback on progress toward their goals	S7: I find the hint/feedback useful.
	- players should always know their status or score	S8: The hint/feedback is given when I need it.
	- players should receive immediate feedback on their actions	S16Bal: I can know immediately that I have made a right or wrong decision.
Immersion	- players should become less aware of their surroundings - players should become less self-aware and less worried about everyday life or self - players should experience an altered sense of time - players should feel emotionally involved in the game - players should feel viscerally involved in the game	S15Bal: I feel relaxed when playing the game. S14Co: I can play the game in a relaxing way because there is no pressure such as time and score. S15Br: I like to race against time and speed. S16Py: I can play the problem solving game in a relaxing way, free from pressure such as time limit.
Social Interaction	- n/a	n/a

Element	Criteria	reduced GameFlow statements
Note: 1. The statements are not in numerical order when appearing in each element of the GameFlow. 2. S1 - S12 are common statements across the four games. S13xx - S16xx are specific statements for individual games, for instance, S13Bal, S13Co, S13Br, S13Py are 13th statement of BALANCE, COMBO, BRAIN, and PYRAMID respectively.		

Table 4.3 28 reduced GameFlow statements for the 33 criteria of the 7 elements of the GameFlow

Element (Sweetser & Wyeth, 2005)	Number of Criteria (Sweetser & Wyeth, 2005)	Number of reduced GameFlow statement
Concentration	6	7
Challenge	4	3
Player Skills	7	5
Control	6	5
Clear Goals	2	1
Feedback	3	3
Immersion	5	4
Social Interaction	n/a	n/a

4.2.1.3 Existing Games: quality sources of powerful features

In order to acquaint powerful game features for developing a new DEG, I have identified a few games on nutrition developed by some professional organizations. As the games have somehow been evaluated by these organizations it can be assumed that they should contain some powerful features. Hence, it was considered beneficial to study from the quality sources and to extract the highly accepted features from them. So, it was decided to use the existing games as quality sources of powerful features. There were several existing games that could be used as sources for assessing children's

preferences for game designs. The highly accepted features were extracted from each of the existing games by children who were end-users of this research study. The collection of highly accepted features was then adapted in the demo version of a new game. A DEG is typically created by game designers or game developers based on their own ideas, not necessarily addressing real requirements of players. In the way of this study, the requirements of the new game came from the real users. This approach is similar to the children game design approach of Duh and associates (2010). They involved children in the design process by encouraging them to develop their own narrative version of a game. However, Duh, et al. (2010) found that children designer lack of game design knowledge, the original design manner from them was not completely workable, adult game developers were needed to concretely implement the children's design into a fully playable game. It can be compared with this study's design approach in the sense of children are encouraged to evaluate the preferred design from the existing games. It could be argued that using existing games as sources is better because children did not need to narrate or design characters of the game by themselves, just picked the characters that they liked from the existing games.

The selected games were used as sources for getting children's opinions (young students aged 7-11 years) about the design of interactive features. The four games are displayed in Figure 4.2 (Chapter 2). Although several existing games were promising potential to be sources for this study, only the four games were selected as the individual game could be played and completed within 10 minutes. Due to a time limit of 50 minutes imposed by the school's timetable to do the empirical study, the four games would be planed to complete by the young students within 40 minutes and the rest 10 minutes for completing questionnaires.

4.2.1.4 Four existing games for Requirements Elicitation

Several web-based free games on nutrition and food have been developed by different professional bodies, including British Nutrition Foundation, National Dairy Council (NDC), National Institutes of Health, Baylor College of Medicine, and the University of Texas Health Science Center. These organizations have the responsibility to provide free supplements to encourage children to learn about healthy eating. The four games are downloadable from the Internet: 'Make a Balanced Plate' (BritishNutritionFoundation, 2011a), 'Combo Kitchen' (NationalDairyCouncil, 2011),

'Pyramid Pile Up Plus' (Playnormous, 2011b) and 'Brain-Gain' (Playnormous, 2011b). Henceforth I refer to them as BALANCE, COMBO, PYRAMID, and BRAIN. All four contain similar educational content about food groups and healthy eating habits, but they have different game components such as visual presentation, manipulation, interaction techniques, and reward/punishment format (Figure 4.2). Such variations are not surprising because different values and assumptions underpin different game designs.

Figure 4.2 The four selected web-based games on nutrition and food developed by different professional bodies, which were used to identify preferable and less preferable game features.

The four selected game have been created deliberately by the professional bodies before launching through their websites. For example, 'Pyramid Pile Up Plus' and 'Brain-Gain' have been created by "Playnormous" which is a team of professional artists, game designers, computer programmers and health researchers. They have experience in collaborating with leading behavior, nutrition and physical activity experts to develop interactive technologies over 10 years through more than $20 million of National Institutes of Health and private industry grants (Playnormous, 2011b, 2011a). Consequently, I believe that the four games are proper prototypes and can be a source and extended to a new game. The selected games were evaluated in order to find out problems which needed to be avoided when implementing a new game, and to extract preferable features which needed to be retained and applied in the new game.

4.2.2 Method

4.2.2.1 Game-Feature Extracting Process

The ultimate goal of this research study is to synthesize most preferable features extracted from the four games to create a powerful game and a robust game design reference model. As the initial step to achieve this goal, the four games were evaluated to identify such features. The evaluation was conducted with the online questionnaire '*Tell Us about the Games*' developed by me, as mentioned earlier. The process is depicted in Figure 4.3.

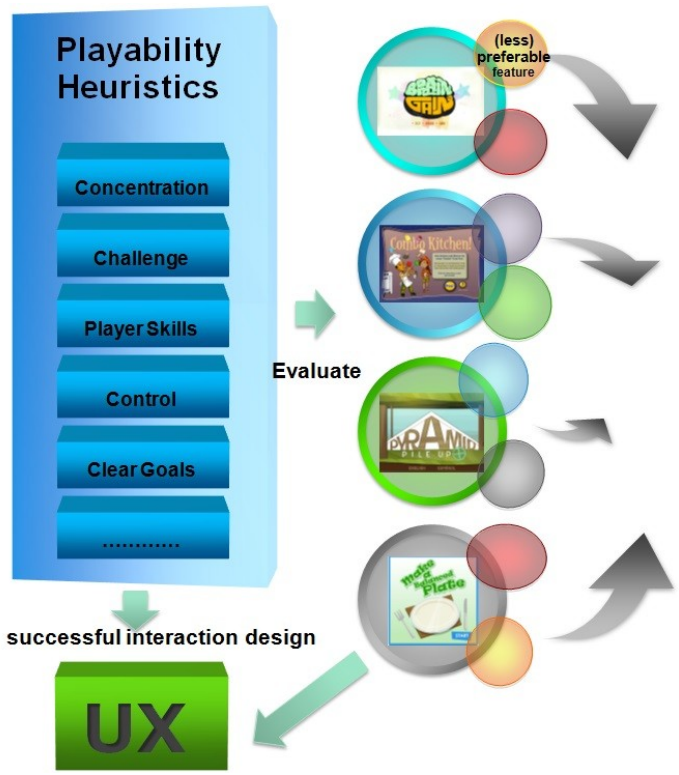


Figure 4.3 The game-feature extracting process: PH was used to evaluate the four games to identify the preferable as well as less preferable features.

4.2.3 Participants and Procedure

A Pilot Study was conducted at a primary school in England. One hundred children aged 7 to 11 years were involved. All the participations were voluntary and consented by the children and their parents. They were intact groups - four classes in Year 3, 4, 5 and 6. A within-subject design was employed; each child was asked to play

and evaluate all the four games on an individual basis in the school's computer lab. A time limit of 50 minutes was imposed as constrained by the school's timetable. The online questionnaire was integrated with the four games. After playing one of the games, a set of 16 statements would be presented. Based on their experience with the game, the children rated each of the statements using a 5-point scale (1: awful, 5: brilliant). 12 statements that were common across the four games and the remaining 4 were specific for individual games; 12+ 4*4 =28 statements) were constructed. Hence, after rating the first game, it was likely that the children became quicker to rate the other games, thereby mitigating the potential problem of mental fatigue. The fun of playing the games could also sustain their motivation. Besides, the children were asked to describe their likes, dislikes and improvement suggestions of the game in the given text boxes. A set of demographic data were collected. Observations were conducted when the children were playing the games and informal interviews afterwards. These data helped to affirm their understanding of the statements.

4.2.4 Results and Discussions

4.2.4.1 The Preferable as well as Less Preferable Features

Due to the time constraint, some children were not able to complete the questionnaire. 64 responses were valid for further analysis: 26 boys and 38 girls. The average age was 10. Only 2 of 64 children never played games. 22 of 64 students played games every day. There were 27, 21, 14 and 2 valid responses from Year 6, 5, 4, and 3, respectively.

The four games with respect to the 28 statements were analysed. As there were two sets of statements; S1 - S12 and S13xx - S16xx; the step of data analysing was slightly different. However, it was based on a multi-step decision-making strategy, which I describe in the following.

S1 - S12 are common statements across the four games. First, I identified the highest means for each of the statements. For example, the overall satisfaction means for statement S1 (graphics style), S2 (colour style), and S4 (word choice) were 4.21, 4.25, and 4.06 respectively (i.e. the bold and underlined numbers in Table 4.4); the most preferred game was COMBO. The most preferred game on S12 (learning strategy) (mean = 3.98) was PYRAMID.

Second, I examined whether the means differed significantly. As the datasets are not normally distributed as indicated by Shapiro-Wilk test ($p < .05$), non-parametric statistical test, Kruskal-Wallis Test, were used for testing the difference among four games. For instance, as shown by the results of a Kruskal-Wallis test was significantly different among the four games with S1 ($H = 11.713$, $p < .05$) (Table 4.4). Then, Mann-Whitney U tests were used for testing the difference between two games. The difference in the level of satisfaction with S1 between COMBO and BALANCE was statistically significant ($U = -2.92$, $p < .05$) and between COMBO and PYRAMID ($U = -3.09$, $p < .05$). However, such difference was ***not*** significant between COMBO (mean = 4.21) and BRAIN (mean = 3.78) ($U = -1.17$, $p > .05$) (Table 4.5).

In deciding which of these two graphics styles (S1) to be used for the new game, I examined whether the differences in the level of satisfaction were related to four demographic variables: year group, gaming habit (i.e. frequency of playing games), preferred game types, and gender. Results showed that there were no significant differences at all with respect to any of the four variables (Table 4.6). Eventually, I chose the graphics style (S1) of COMBO, given its highest mean.

However, the instantiations with the highest means were not necessarily chosen for my new game. For example, the level of satisfaction with S3 (text size) of COMBO was the largest (mean = 4.17) (i.e. the italic and underlined numbers in Table 4.4). However, as shown by the results of a Kruskal-Wallis test was ***not*** statistically significantly higher than that of BALANCE, BRAIN, and PYRAMID ($H = .462$, $p > .05$), as shown in Table 4.4.

Then I applied the same approach to check whether any of the four demographic variables had any effect. It was found that there was significant difference in the level of satisfaction with S3 (text size) of COMBO between boys and girls ($H = 4.22$, $p < .05$), whereas no such significant difference could be found for PYRAMID, as shown in Table 4.7. Hence, I decided to use the text size (S3) of PYRAMID (mean = 4.12) for the new game. Otherwise, the text size of COMBO might lead to gender bias.

For S13xx - S16xx, the statements are specific statements for individual games; no difference testing among four games was needed. After the means for each of the statements were identified (Table 4.4), the differences in the level of satisfaction related to four demographic variables were examined.

The above examples illustrate how the empirical findings enabled me to identify preferable features of each game. In Table 4.4, it shows how the 28 statements are best met and worst met. With these results, I planned how to make two new games on food and nutrition: FoodGroups-A and FoodGroups-B. Both games would be developed based on the guiding of the preferable as well as less preferable game features extracted from the games. Table 4.8 shows that FoodGroups-A was aimed to have the most preferable features from the four selected games (i.e. graphics style (S1), colour style (S2), and word choice (S4) of COMBO; text size (S3) and learning strategy (S12) of PYRAMID) whereas FoodGroups-B would have the less preferable ones.

Table 4.4 The highest means and the difference in the level of satisfaction with *all features* (28 reduced GameFlow statements) among four games

Statement	**BALANCE**			**COMBO**			**BRAIN**			**PYRAMID**			**Difference**	
	Mean	**N**	**Std.**	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**H**	***P***
S1	3.66	47	1.006	**4.21**	53	.840	3.78	50	1.360	***3.42***	43	1.295	11.713	**.008***
S2	3.91	47	.996	**4.25**	53	.782	4.00	50	1.178	***3.74***	43	1.136	5.150	.161
S3	4.11	47	.983	***4.17***	53	.914	***4.08***	50	1.085	**4.12**	43	1.219	.462	.927
S4	3.91	47	.929	**4.06**	53	1.045	***3.76***	50	1.422	4.05	43	1.413	3.591	.309
S5	**4.07**	45	.889	4.00	50	1.178	3.70	50	1.182	***3.31***	42	1.405	8.945	**.030***
S6	3.87	45	.968	3.60	50	1.485	**4.10**	50	1.111	***3.50***	42	1.469	4.581	.205
S7	**3.69**	45	.996	3.52	50	1.359	3.62	50	1.292	***3.26***	42	1.363	2.595	.458
S8	3.49	45	1.199	***3.12***	50	1.612	**3.76**	50	1.422	3.38	42	1.396	4.869	.182
S9	***3.82***	45	1.173	4.06	50	1.114	***3.82***	50	1.508	**4.12**	42	1.234	2.364	.500
S10	3.69	45	1.203	***3.92***	50	1.226	**3.78**	50	1.447	***3.64***	42	1.322	1.882	.597
S11	***3.44***	45	.990	3.54	50	1.232	3.68	50	1.392	**3.76**	42	1.100	3.718	.294
S12	***3.71***	45	1.036	3.78	50	1.298	3.82	50	1.395	**3.98**	42	1.115	2.055	.561
S13Bal	3.66													
S14Bal	3.91													
S15Bal	3.80													

Statement	BALANCE			COMBO			BRAIN			PYRAMID			Difference	
	Mean	N	Std.	Mean	N	Std.	Mean	N	Std.	Mean	N	Std.	H	*P*
S16Bal	3.82													
S13Co				3.49										
S14Co				4.16										
S15Co				3.84										
S16Co				4.10										
S13Br							3.50							
S14Br							3.58							
S15Br							3.68							
S16Br							3.42							
S13Py										3.34				
S14Py										3.49				
S15Py										3.49				
S16Py										3.49				
Note: bold and underline number = best cases; bold and italic number = worst case														

Table 4.5 The highest means and the difference in the level of satisfaction with *related features* (reduced GameFlow statements) between two games

Statement	Game	Mean	N	Std.	BALANCE		COMBO		BRAIN	
					U	*p*	U	*p*	U	*P*
S1	**BALANCE**	3.66	47	1.006	-	-	-	-	-	-
	COMBO	**4.21**	53	0.840	**-2.922**	**0.003***	-	-	-	-
	BRAIN	3.78	50	1.360	-1.153	0.249	-1.176	0.240	-	-
	PYRAMID	3.42	43	1.295	-0.620	0.535	**-3.091**	**0.002***	-1.559	0.119
S5	**BALANCE**	**4.07**	45	0.889	-	-	-	-	-	-
	COMBO	4.00	50	1.178	-0.281	0.779	-	-	-	-
	BRAIN	3.70	50	1.182	-1.339	0.181	-1.539	0.124	-	-
	PYRAMID	3.31	42	1.405	-2.463	**0.014***	-2.484	**0.013***	-1.276	0.202

Table 4.6 The differences in the level of satisfaction on four demographic variables with S1 (graphics style)

demographic variables	S1 (graphics style) of COMBO					
	groups	Mean	N	Std.	H	*P*
year group	**Year3-4**	4.29	14	1.07	0.928	0.629
	Year5	4.17	12	0.72		
	Year6	4.19	27	0.79		
frequency of playing games (per week)	**2 days or less**	4.36	14	1.15	4.191	0.123
	3-5 days	4.32	19	0.67		
	Everyday	4.00	20	0.73		
preferred game types	**Educational games**	3.80	5	1.64	1.88	0.597
	Sensorimotor games	4.11	19	0.88		
	Strategy games	4.25	20	0.63		
	Sport games	4.56	9	0.52		
gender	**Boy**	4.36	22	0.79	1.42	0.233
	Girl	4.10	31	0.87		

Table 4.7 The differences in the level of satisfaction on four demographic variables with S3 (text size)

demographic variables	groups	S3 (text size)																			
		BALANCE					COMBO					BRAIN					PYRAMID				
		Mean	N	Std.	H	*p*	Mean	N	Std.	H	*p*	Mean	N	Std.	H	*p*	Mean	N	Std.	H	*p*
year group	Year3-4	4.09	11	0.83	1.027	0.598	4.07	14	0.99	0.170	0.919	4.36	11	1.20	3.077	0.215	4.42	12	0.90	1.959	0.375
	Year5	3.91	11	1.04			4,25	12	0.75			3.67	12	1.30			4.20	10	1.47		
	Year6	4.20	25	1.04			4.19	27	0.96			4.15	27	0.90			3.90	21	1.26		
frequency of playing games (per week)	2 days or less	4.29	14	0.91	0.495	0.781	4.36	14	1.00	1.592	0.451	4.00	14	1.30	5.825	0.054	4.31	16	1.40	2.320	0.313
	3-5 days	4.06	16	1.06			4.16	19	0.76			4.53	15	0.64			4.08	13	0.86		
	Everyday	4.13	16	0.88			4.05	20	0.99			3.68	19	1.10			3.93	14	1.32		
preferred game types	Educational games	3.50	2	0.70	2.249	0.522	3.40	5	1.14	5.979	0.113	4.00	3	0.00	2.881	0.410	4.25	4	0.95	3.369	0.338
	Sensorimotor games	4.15	20	1.18			4.37	19	0.68			4.33	21	0.96			4.00	15	1.25		
	Strategy games	4.00	15	0.92			4.00	20	1.02			3.79	14	1.25			3.79	14	1.47		
	Sport games	4.30	10	0.67			4.56	9	0.72			4.00	12	1.20			4.70	10	0.67		
Gender	Boy	4.26	23	1.05	2.177	0.140	4.45	22	0.80	**4.220**	**0.040***	4.00	26	1.29	0.021	0.884	4.11	18	1.32	0.012	0.913
	Girl	3.96	24	0.92			3.97	31	0.94			4.17	24	0.81			4.12	25	1.16		

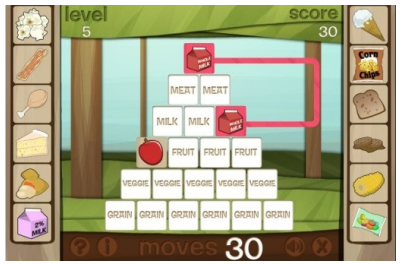
Table 4.8 The example of compositions of the two new games with most preferable features, FoodGroups-A, and the less preferable ones, FoodGroups-B, from the four selected games (cf. Table 4.4)

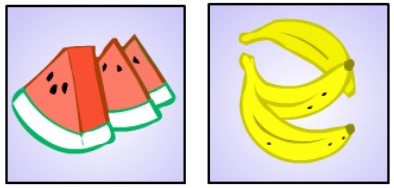
Game	(Less) Preferable features of selected games
FoodGroups-A	S1_Co + S2_Co + S3_Py + S4_Co + S12_Py + ...
FoodGroups-B	S1_ Py + S2_ Py + S3_ Br + S4_Br + S12_Bal +....
Note: Bal = BALANCE, Co = COMBO, Br = BRAIN, Py = PYRAMID	

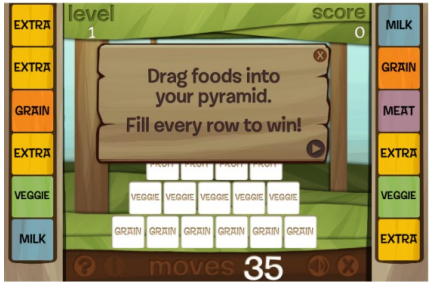
However, when considering the fact of the closeness of the means between the most and the least preferable features, it might be discussed that it was inequitable to decide absolutely that a game feature with the highest means should be selected as the most preferable feature despite these means were very close as well as they were in the same range. For example, to decide to select the text feature, the text style of PYRAMID was selected as the most preferable text feature because of its highest means (4.12) and the text style of BRAIN was selected as the least preferable text feature because of its lowest means (4.08), as shown in Table 4.4. It might be due to this research study used only four games for extracting the feature, children might have similar opinion on the text feature of these games. It might be better if there were more choices of games which contain more various feature of text style. To reduce the problem, the choices of games should be increased in the future study.

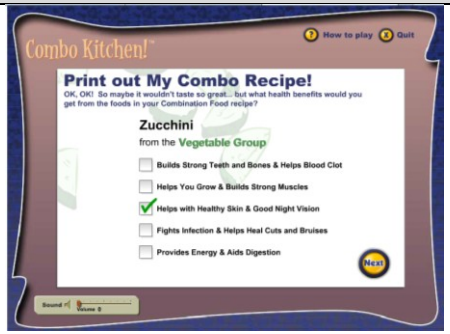
Eventually, the preferable as well as less preferable features of each game were identified and summarised according to the numerical order of the statements as shown in Table 4.9. Such features would be synthesized to create two DEG on food groups. The plan to adapt those features in a game is also proposed in the table.

Table 4.9 Analysed data grouped by the element of the GameFlow model

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S1:** In terms of *graphic style,* the highest mean was COMBO; the overall satisfaction means was 4.21. - The level of satisfaction with *graphic style* of COMBO was significantly different from BALANCE and PYRAMID; which had the lowest mean respectively. So, the feature of BALANCE and PYRAMID could not be selected as preferable feature, given its lower mean. - However, such difference was *not* significant between COMBO and BRAIN. - For COMBO there were no significant differences at all with respect to any of the four demographic variables: year group, gaming habit (i.e. frequency of playing games), preferred game types, and gender. But, for BRAIN, there were significant differences with respect to gaming habit. - Eventually, the *graphics style* of COMBO was chosen, given its highest mean and homogenous preference of children. - Children's comments on COMBO; • "Backgrounds pictures looked creative."	- Cartooned humans are included as graphics/pictures in COMBO.  - Children felt they are more appealing than graphics used in BALANCE and PYRAMID. There are no cartooned human, only food pictures are used in those games. 	- Most children preferred more on a game illustrates with mix-gender characters, such as both male and female chefs in a scene. Games use only monsters could not get the most preference. A game with no main character, such as presenting just food objects, got the less preference. - Graphics/pictures of FoodGroups-A would be a cartoon-like style. - Especially, cartooned humans would be included in FoodGroups-A.	- Graphics/pictures of FoodGroups-B would look like a human-like style. It would not be funny, for example a serious male chefs.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
• "Pictures were set out nice to show which combination choices there are." • "Some graphics were not very well clear."			
- **S2:** In terms of *colour style,* the highest mean was COMBO; the overall satisfaction means was 4.25. - However, the level of satisfaction with *colour style* of COMBO was *not* statistically significantly higher than that of BALANCE, BRAIN, and PYRAMID. - There were no significant differences at all with respect to any of the four demographic variables of children of COMBO, BALANCE, and BRAIN, except PYRAMID which was significant different with respect to game types. - Eventually, the *colour style* of COMBO was chosen, given its highest mean and homogenous preference of children. - Children's comments on COMBO; • "The colours of fruits were clear." • "Some pictures' texture was not clear. It had no funny things."	- Colours used in COMBO's picture are clear.  - However, some picture (as below) was not understandable enough by children.  - Colours used in PYRAMID's picture are dull, not colourful.	- Graphics/pictures of FoodGroups-A would not have a lot of textures; solid colours of cartoon style would be applied. - Just a picture with clear colour is not enough to make it understandable for children. The exact name of the picture should be given to help it more understandable. In FoodGroups-A, a food name would be provided as text hint when mouse is hovered over the picture.	- Graphics/pictures of FoodGroups-B would dull and pale. - A food name would be provided as text hint, but it would stick on or beside the pictures all the time.

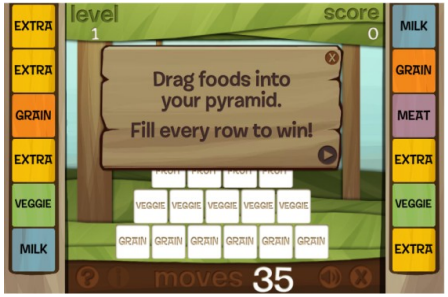
Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S3:** In terms of *text size style,* the highest mean was COMBO; the overall satisfaction means was 4.17. - However, the level of satisfaction with *text size style* of COMBO was *not* statistically significantly higher than that of BALANCE, BRAIN, and PYRAMID. - There was significant difference in the level of satisfaction with the text size of COMBO between boys and girls, whereas no such significant difference could be found for PYRAMID, which had second highest mean. - Eventually, the *text size style* of PYRAMID was chosen; the overall satisfaction means was 4.12. - Children's comments on PYRAMID; • "The size of writing was proper."	- The text size of PYRAMID is really clear and big enough for children. Also style is easy to understand.  - The style and size of text used in BRAIN are too various, not stable. Some text style is difficult to read.	- The text size style of PYRAMID would be applied in FoodGroups-A.	- The text size and style of FoodGroups-B would be various and not stable.
- **S4:** In terms of *word choice,* the highest mean was COMBO; the overall satisfaction means was 4.06. - However, the level of satisfaction with *word choice* of COMBO was *not* statistically significantly higher than that of BALANCE, BRAIN, and PYRAMID. - There were no significant differences at all with respect to	- COMBO uses simple and understandable words for children. - However, some choices of words used for explaining about nutrition were difficult for children such as Aid Digestion.	- FoodGroups-A would not contain deep information about nutrition. Only the information on food groups would be taught. It would be presented with simple and understandable words by children aged 7-11 years.	- FoodGroups-B would contain deep information about nutrition. It would be presented in a part of tutorial.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
any of the four demographic variables of children of COMBO, BALANCE, and PYRAMID, except BRAIN which was significant different with respect to year group, and gaming habit. - Eventually, the *word choice* of COMBO was chosen, given its highest mean and homogenous preference of children. - Children's comments on COMBO; • Some words were difficult.	 - Some choices of words used in BRAIN are difficult for children.		
- **S5:** In terms of *the instructions,* the highest mean was BALANCE; the overall satisfaction means was 4.07. - The level of satisfaction with *the instructions* of PYRAMID; which had the lowest mean; was significantly different from BALANCE, and COMBO. So, the feature of PYRAMID could not be selected as preferable feature, given its lower mean. - However, such difference was *not* significant between BALANCE, COMBO and BRAIN. - For BALANCE, COMBO, and BRAIN, there were no significant differences at all with respect to any of the four demographic variables: year group, gaming habit (i.e.	- BALANCE presents a page of instructions before starting game. There are a few lines of text-based instructions. It contrasts with PYRAMID which presents multiple pages of instructions before starting game. - The most children agreed that a page of BALANCE's instructions is nice. It provides main steps of how to play game as well as goals of the game. Only few of them thought there were	- Children prefer a short instruction on how to play game and goals of the game before starting game. Thus, FoodGroups-A would be designed to have a page of short, overview instructions which would be presented on the first page before starting game.	- Without an instruction page, the game might be not playable. Thus, FoodGroups-B would have same design of an instruction page which presented goals of the game and how to play game before starting game.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
frequency of playing games), preferred game types, and gender. - Eventually, the *graphics style* of BALANCE was chosen, given its highest mean and homogenous preference of children. - Children's comments on BALANCE; • "There were not many instructions. It did not tell what to do; I also did not get it."	not enough instructions to help them understand how to play the game. 		
- **S6:** In terms of *the easiness to understand how to play the game,* the highest mean was BRAIN; the overall satisfaction means was 4.10. - However, the level of satisfaction with *the easiness to understand how to play the game* of BRAIN was *not* statistically significantly higher than that of BALANCE, COMBO, and PYRAMID. - There were no significant differences at all with respect to any of the four demographic variables of children of COMBO, BALANCE, BRAIN, and PYRAMID. - *The easiness to understand how to play the game* of BRAIN was chosen, given its highest mean and homogenous preference.	- BRAIN does not force children to read instructions before starting game; there is no instruction page before playing game. However, the game provides a "how to play" link at the navigation bar for children can navigate if needed. It informs brief instructions in short, text-based form.	- Children can know how to play a game by their own even instruction is not given before starting game. However, a help page with detail of how to play the game should be provided in case some children might need it. FoodGroups-A would be designed to have help link to explain how to play the game.	- The understandable instruction seems to be necessary to play a game by their own, a help page should be provided for children. FoodGroups-B would be designed to have help link to explain how to play the game.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S7:** In terms of *useful hint/feedback,* the highest mean was BALANCE; the overall satisfaction means was 3.69. - However, the level of satisfaction with *useful hint/feedback* of BALANCE was *not* statistically significantly higher than that of BRAIN, COMBO, and PYRAMID. - There were no significant differences at all with respect to any of the four demographic variables of children of COMBO, BALANCE, and PYRAMID, except BRAIN which was significant different with respect to gender. - Eventually, the *useful hint/feedback* of BALANCE was chosen, given its highest mean and homogenous preference of children. - Children's comments on BALANCE; • "I liked the game in the sense of the way it shows the hints because they are clear." • "The instructions made me know what food goes in its vitamin, what type of food they are."	- BALANCE provides informative hint/feedback for children to accommodate their playing. For example, when hovering the mouse over an object/picture, information of the object/picture, such as name of the food group, will be informed. It looks like a hint and it is useful for making a decision.  - While playing game, interactive feedback is also employed to inform the result of a decision such as a food picture bounces back suddenly to its original position if children put it in a wrong food group. The feedback	- Hint would be provided in FoodGroups-A, such as different five colours were assigned to different five food groups. Children could recall the name of the food group when seeing a colour. - Informative feedback such as showing hint text when rolling mouse over an object would be applied to design hint/feedback of FoodGroups-A. For example, if some food pictures might be not clear enough for children, name of the food would be shown when the mouse is hovered over the picture. - Interactive feedback, such as bouncing technique, would be applied to FoodGroups-A's design. It helps children know immediately that they have a right or wrong decision. Children are able to develop their learning by the	- No hint would be provided in FoodGroups-B. Children needed to remember different names of the five food groups by themselves. - The name of the food was presented on/beside the food picture, not in form of demanding hint.

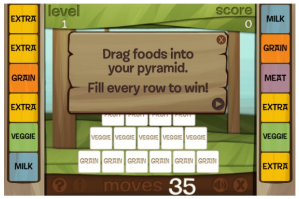
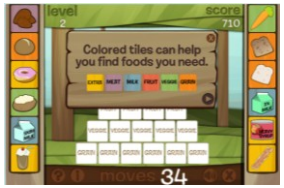
Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
	helps children know immediately that they have a wrong decision. Children need to have a matching again to find the right answer. - For PYRAMID, when the game becomes progressively more difficult, the hint colour behind the food disappears, it is too much difficult for children to guess the decision.	interactive feedback.	
- **S8:** In terms of *the hint/feedback is given when needed,* the highest mean was BRAIN; the overall satisfaction means was 3.76. - However, the level of satisfaction with *the hint/feedback is given when needed* of BRAIN was *not* statistically significantly higher than that of BALANCE, COMBO, and PYRAMID. - There were no significant differences at all with respect to any of the four demographic variables of children of COMBO, BALANCE, PYRAMID, and BRAIN. - Eventually, the *hint/feedback is given when needed* of	- BRAIN applies score, and wording such as "CORRECT" or "INCORRECT" to send feedback of a decision children have made. They can know immediately their progress. 	- In FoodGroups-A, to inform children's progress, score would be applied as feedback which sent immediately. Moreover, instead of just wording such as "Well done", "Great" but sound effect of the wording would be applied to send feedback of a decision children have made.	- FoodGroups-B would provide feedback to inform the decision, but less than FoodGroups-A. - The feedback is just plain text such as "Well Done" and "Try Again". - No score feedback to inform children's progress.

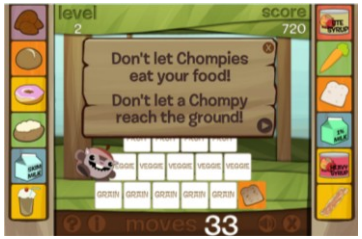
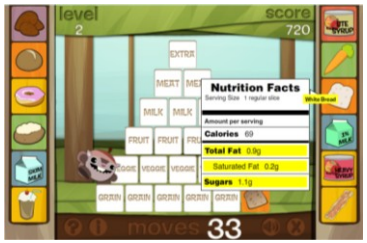
Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
BALANCE was chosen, given its highest mean and homogenous preference of children.	- Whereas, COMBO does not applies score to inform progress. It uses wording such as "Right" to send feedback of children's progress. 		
- **S9:** In terms of *the easy technique (click, drag and drop),* the highest mean was PYRAMID; the overall satisfaction means was 4.12. - However, the level of satisfaction with *the easy technique (click, drag and drop)* of PYRAMID was *not* statistically significantly higher than that of BALANCE, BRAIN, and COMBO. - There were no significant differences at all with respect to any of the four demographic variables of children of COMBO, BALANCE, BRAIN, and PYRAMID. - Eventually, the *the easy technique (click, drag and drop)* of	- PYRAMID uses simple techniques like click, drag and drop for controlling the gameplay. It is easy to understand and to play. 	- Easy techniques like click, drag and drop would be applied for controlling FoodGroups-A.	- FoodGroups-B also applied easy techniques like click, drag and drop for controlling, however, the speed of controlling is needed.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
PYRAMID was chosen, given its highest mean and homogenous preference of children. - Children's comments; • "I liked putting it in the right places" • "I didn't like when it didn't give me the foods I need." • "I dislike when I put them in the right places it never went."	- BALANCE and BRAIN, which were not statistically significantly different lower than PYRAMID, also uses simple techniques like click, drag and drop for controlling the gameplay. However, the speed of controlling is needed.		
- **S10:** In terms of *animation effect,* the highest mean was COMBO; the overall satisfaction means was 3.92. - The level of satisfaction with *animation effect* of COMBO was *not* statistically significantly higher than that of BALANCE, BRAIN, and PYRAMID. - But, there was significant difference in the level of satisfaction with the *animation effects* of COMBO between boys and girls, Boys' satisfaction means was 4.40, whereas girls'satisfaction means was 3.60. Whereas no such significant difference could be found for BRAIN, which had second highest mean. - Eventually, the *animation effects* style of BRAIN was chosen; the overall satisfaction means was 3.78.	- Actually, the highest mean satisfaction on animations effect was COMBO, but boys and girls have significantly different satisfaction. Boys preferred COMBO more than girls. - Cartooned males are used as main character models in every scene of COMBO such as a smart chef, a strong male cartoon. It might be more appealing to boys than girls.	- Cartoon style with exaggerated expressions would be applied to create funny animation effects of FoodGroups-A. - Moreover, different genders have different preference such as boys prefer cartooned male characters. FoodGroups-A would be illustrated by mix-gender cartooned humans, such as a male chef and a female chef.	- No funny animation effects applied for FoodGroups-B. Cartoon for FoodGroups-B could not move themselves. - Cartoon for FoodGroups-B was a chef man. No mix-gender cartooned humans illustrated in FoodGroups-B.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- Children's comments on BRAIN; • "I liked how the foods come out and come in swerving way." • "I liked the angry monster was fired."	  - Children have the homogenous preference on BRAIN's animation effect. Cartoon style with exaggerated expressions are used to make funny animation effects such as swerving objects, a dancing clock, and an angry burnt monster.		

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
	 - However, there are very small amount of animation effect for PYRAMID. Only the Chompies can move a little bit.		
- **S11:** In terms of *sound effect,* the highest mean was PYRAMID; the overall satisfaction means was 3.76. - However, the level of satisfaction with *sound effect* of PYRAMID was *not* statistically significantly higher than that of BALANCE, BRAIN, and COMBO. - There were no significant differences at all with respect to any of the four demographic variables of children of PYRAMID, BALANCE, and COMBO, except BRAIN which was significant different with respect to gaming habit. - Eventually, the *sound effects* style of PYRAMID was chosen, given its highest mean and homogenous preference of children.	- PYRAMID applies different sound effects for different actions such as sound effect of performance feedback is different between right and wrong decision. - Whereas, BALANCE does not apply any sound effects to the game.	- FoodGroups-A would apply different sound effects for different actions such as sound effect of performance feedback, sound effect of character action.	- FoodGroups-B would not apply any sound effects for any actions.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S12:** In terms of *learning strategy,* the highest mean was PYRAMID; the overall satisfaction means was 3.98. - However, the level of satisfaction with *learning strategy* of PYRAMID was *not* statistically significantly higher than that of BALANCE, BRAIN, and COMBO. - There were no significant differences at all with respect to any of the four demographic variables of children of COMBO, BALANCE, BRAIN, and PYRAMID. - Eventually, the *learning strategy* of PYRAMID was chosen, given its highest mean and homogenous preference of children. - Children's comments on PYRAMID; • "The game looks like a jungle. The idea was all right."	- In PYRAMID, first level presents name tiles of the five food groups accompanied with their own colours, such as a green tile means vegetable group, a blue tile is milk group.  - Second level presents food tiles without their group name accompanied with their own colours, such as a carrot on green tile belongs to vegetable group. It helps children can distinguish which food belongs to which group. It is easy to remember the food group though the colours. 	- FoodGroups-A would gradually deliver the knowledge on food groups though each level of the game. - The lower levels would provide essential prerequisite information for playing later levels. - The higher levels would be gradually harder than the previous levels. - Technique of repetition would be applied for training children's memory about food groups. - Children preferred the strategy of providing reminders for them. Different colours are used for helping children to remember different food groups. Colours are used as hints to remind children in the first level and gradually reduced in higher level until no colour hint	- FoodGroups-B would apply just a simple matching technique, no specific strategy is applied. Children just match a food with its right group. There were no level to provide prerequisite knowledge.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
	- At the same time, Chompies which are obstacles will come to make game more exciting.  - When rolling mouse over a food tile, nutrition information will be presented as well.  - When passing to higher levels until reaching level 5, tiles will have no colour hinting. The leveling game can support children increase their memory on food groups gradually.	in highest level. Colour hinting would be incorporated to FoodGroups-A for helping children recall their memory about the food groups. - Background picture of FoodGroups-A would be related to food concepts such as a restaurant or a food factory.	

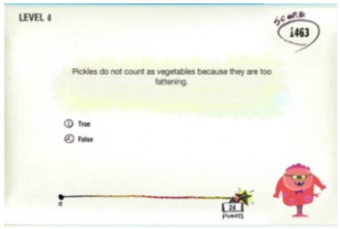
Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
	 - Whereas, BALANCE is just a simple matching game, no specific strategy is applied.		
- **S13Bal:** In terms of *the unnecessary of instructions*; the overall satisfaction means of BALANCE was 3.66. - There were no significant differences at all with respect to any of the four demographic variables of children.	- BALANCE forces children to read instructions before starting game. Children tended to ignore reading the instructions as they agreed that they could play the game without reading the manual, just seeing the pictures in the game and making some guesses for how to play.	- Children can start playing a game on their own, children aged 7-11 years are eager to play games, they tend to ignore instructions. - FoodGroups-A's instructions would be not too long and able to skip by children if they do not need to read them.	- As children tend to ignore the instruction, FoodGroups-B's instructions would be not too long and able to skip by them if they do not need to read.
- **S14Bal:** In terms of *being a simple game which can be played in a short time*; the overall satisfaction means of BALANCE was 3.91. - There were no significant differences at all with respect to	- BALANCE is a no level game. It can be played completely in a short time. Most children preferred the simplicity of the game, although a	- FoodGroups-A would be designed to be simplistic to play. It can be completed in a short time. It uses easy words about food groups, easy	- FoodGroups-B would be designed to be completed in a short time. It uses easy technique to control such as

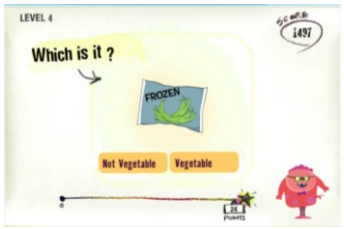
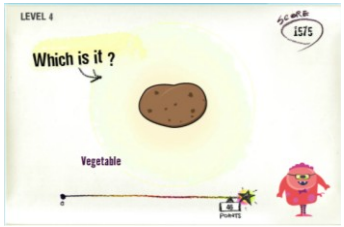
Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
any of the four demographic variables of children. - Children's comments on BALANCE; • "The game was very simple, easy to understand and to play." • "It was a very short game. It had nothing exciting. I would like it more if it had more of a challenge." • "Some words were hard for me."	few of them felt it is not exciting.	technique to control such as matching food pictures with the food group names. - However, a game without any level was not preferred by some of the children aged 7-11 years. FoodGroups-A would be designed as a multi-sub-games or multi-levels game in order to increase challenges in game and each sub-game/each level would be simplistic to play.	matching food pictures with the food group names. - FoodGroups-B would be designed as a single-levels game.
- **S15Bal:** In terms of *being a relaxing game*; the overall satisfaction means of BALANCE was 3.80. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on BALANCE; • "The game was fun, I liked everything". • "It was a bit boring".	- BALANCE is a simple game. It has no pressures such as speedy time, penalty score, and obstacles. Most children liked it; they felt relaxed when playing the game. Although a few of them felt it was boring.	- Initial levels of FoodGroups-A would not have any pressure features such as speedy time, penalty score, and obstacles.	- FoodGroups-B would have some pressure features such as speedy time, penalty score, and obstacles.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S16Bal:** In terms of *immediately feedback*; the overall satisfaction means of BALANCE was 3.82. - There were no significant differences at all with respect to any of the four demographic variables of children.	- Although BALANCE does not provide score as instant feedback to report children' progression, but children agreed that they could determine their decision immediately by another interactive feedback such as if children made a wrong matching of a food picture and a food group, the food picture bounces back. Such feedback encourages children to try again to find a right matching or a right answer.	- To inform children know immediately that they have made a right or wrong decision, not only score, but also other kinds of informative feedback would be applied to FoodGroups-A's design such as bouncing objects.	- There were no score to immediately inform children of their progress in FoodGroups-B. They would know immediately that they have made a right or wrong decision by other kinds of informative feedback such as by wording "Weldone", "Try Again".
- **S13Co:** In terms of *providing clear goals*; the overall satisfaction means of COMBO was 3.49. - There were no significant differences at all with respect to any of the four demographic variables of children.	- COMBO is only one game that provides a learning goal at the first page before starting game. - "A Combination Food is a food that is made up of foods from more than one food group.", it is a learning goal which COMBO provides. - The goal is rather not clear enough	- FoodGroups-A would provide a learning goal before starting game. Importantly, it would be clear enough in order to motivate children to reach such as "Do you know which food belongs to which group?"	- Same as FoodGroups-A, it would not be playable if FoodGroups-B not provide a goal before starting game. The goal was also clear enough in order to motivate children to reach.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
	for children to motivate them to reach. So, children did not completely agree that they can tell which ingredients are in combination foods. 		
- **S14Co:** In terms of *being a relaxing game*; the overall satisfaction means of COMBO was 4.16. - But, there was significant difference in the level of satisfaction with the *being a relaxing game* of COMBO between boys and girls. Boys' satisfaction means was 4.45, whereas girls' satisfaction means was 3.97. - Children's comments on COMBO; • "It was really fun.", "It was very exciting." • "It was a very good health game." • "I liked when I could analyze the combination of pizza."	- COMBO is designed to have no pressures such as time limit or penalty score. Children agreed that they can play the game in a relaxing way. - However, boys and girls had different opinion on the feature. Boys felt COMBO is relaxing for them than girl felt. In the point of view of boys, relaxation might become boredom if a game has no any pressure to challenge them.	- Harder levels of FoodGroups-A would be designed to have appropriate pressures such as penalty score, speedy objects. The appropriate pressure can let girls play the game with low tension, but motivate boys to play with more challenge. Both genders can play the game in a relaxing way.	- FoodGroups-B would be designed to have more pressures than FoodGroups-A such as more speedy objects.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S15Co:** In terms of *multi-levels of challenge*; the overall satisfaction means of COMBO was 3.84. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on COMBO; • "The game was too easy. It would be more challenging."	- COMBO is a multi-levels game. - Each level uses different presentations to deliver different information on nutrition; such as 1st level lets children choose a number of combination foods. Then, the combination foods are sent to the 2nd level for testing children analysing how many food groups they have. - The design of COMBO is *good* in the sense of children can move to the other levels, which provide higher information on nutrition, if they can accomplish the previous ones. - However, the game has no obstacles to challenge children that why they thought the game was too easy. Children suggested it should be more challenging.	- To design FoodGroups-A to have the feature of increasing the level of challenge as the children progresses through the game with their increasing skills; it would be designed as a multi-levels game. - Different presentations would be applied to each level to deliver information on food groups, such as 1st level lets children remember the five colours of five food groups. Then, 2nd level lets them match foods with its groups. Finally, a level allows them pick their own food from different food groups to make a balanced meal. - Also, the higher levels would have obstacles to challenge children to play.	- FoodGroups-B would be a no-level game. It would not have the feature of increasing the level of challenge as the children progresses through the game with their increasing skills.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S16Co:** In terms of *appropriate reward for skill development*; the overall satisfaction means of COMBO was 4.10. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on COMBO; • "It was fast game." • "It was really interesting." • "It was nice and easy to understand and play."	- Children thought the COMBO is a game that can be played and completed in a short time. It uses simple technique to control game that is just click. - COMBO provides different levels for children who can accomplish their effort in previous levels. For example, children preferred that they have chance to make their own recipe for a combination food at last level of the game.	- FoodGroups-A would be designed to allow different styles of playing such as providing a challenging level for children to make their own balance meal if they can progress though the game. It allows children to apply their knowledge being gained.	- FoodGroups-B would not be designed to allow different styles of playing due to it would have only one level.
- **S13Br:** In terms of *design of quiz games*; the overall satisfaction means of BRAIN was 3.50. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on BRAIN; • "There were many levels in the game. There were different questions in the different levels. I could learn more on healthy foods in different ways." • "The questions were either not too hard or too easy to	- Although BRAIN is a quiz game, but each level use different presentations to present nutrition information such as following; - Using text as questions and choices. 	- In order to make FoodGroups-A challenging, some levels in the game would be designed as quiz games which have different presentations in each level such as multiple choices and matching pictures.	- FoodGroups-B would not be designed to have different presentations due to it would have only one level.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
answer.”	- Using static pictures as questions and choices.  - Using animation as questions and choices. 		
- **S14Br:** In terms of *the unnecessary of instructions*; the overall satisfaction means of BRAIN was 3.58. - There were no significant differences at all with respect to any of the four demographic variables of children.	- Although BRAIN does not provide an instruction page before starting game, children thought they can know how to play the game without reading instructions. - Perhaps BRAIN is a quiz game, children can start playing a game on	- However, FoodGroups-A would provide a help page describing “how to play” in case some children may need it.	- However, FoodGroups-B would provide a help page describing “how to play” in case some children may need it.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
	their own even instruction is not given. - However, BRAIN provides a "how to play" page in case some children may need it.		
- **S15Br:** In terms of *speed and time pressure*; the overall satisfaction means of BRAIN was 3.68. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on BRAIN; • "I enjoyed BRAIN because it was interesting." • "I liked that the game was a fun and entertaining game." • "It took a bit long, the time ran out really quickly, I had to answer the question fast". • "The time limit made game challenging. However, the time was too fast, it did not really give me a chance to read questions."	- BRAIN applies pressure features to the game such as children have to answer a quiz as quick as they can before time is up; they have to match picture which come in and go out at very fast speed. Children preferred to race against time and speed. However, they suggested that they felt more enjoyed if the time run slowly. - However, the game provides many levels which repeat the same presentations, same techniques, same speed of time and sometimes same questions, so children felt it is rather long to be completed.	- Some pressure features such as speedy objects and obstacles would be applied to design FoodGroups-A, but they would be set at an appropriate rate for children's relaxing play.	- FoodGroups-B would be designed to have more pressure features than FoodGroups-A, such as more speedy objects and obstacles, also they would be set at faster rate.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
- **S16Br:** In terms of *multi-levels of challenge*; the overall satisfaction means of BRAIN was 3.42. - There were no significant differences at all with respect to any of the four demographic variables of children.	- BRAIN is a game with more than one level. Each level presents different information on nutrition. - However, each level is not related to consecutive levels. Information from previous levels cannot be applied to play later levels. - When comparing with COMBO and PYRAMID, it found that BRAIN could get the least overall satisfaction in terms of multi-levels of challenge. It can be assumed that different situations make children more curious if those situations are related.	- FoodGroups-A would have more than one level like BRAIN. Moreover, each level would be related to consecutive levels such as the previous levels to provide necessary information for playing higher levels.	- FoodGroups-B would have only one level. No level would be provided necessary information for playing game.
- **S13Py:** In terms of *being a problem solving game*; the overall satisfaction means of PYRAMID was 3.34. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on PYRAMID;	- Children did not completely agree that PYRAMID was a problem solving game. They thought it was just a game with obstacles that challenge them to play. - It was simple and easy to understand	- FoodGroups-A would be designed to have some obstacles to make the game more challenging.	- FoodGroups-B would be designed to have more obstacles than FoodGroups-A.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
• "It was simple and easy to understand and to play".	and to play because just drag and drop technique was used for playing.		
- **S14Py:** In terms of *how to overcome obstacles*; the overall satisfaction means of PYRAMID was 3.49. - There were no significant differences at all with respect to any of the four demographic variables of children.	- The PYRAMID's instruction does not inform how to get rid of the obstacles. - Children tried to beat the obstacles, but they were confused on how to get rid of them. Thus, they had neutral preference with the obstacles (Chompies) because of not enough detail of instructions.	- The higher levels of FoodGroups-A would have obstacles, children would be provided with instructions of how to overcome the obstacles.	- FoodGroups-B would have obstacles, children would be provided with instructions of how to overcome the obstacles.
- **S15Py:** In terms of *multi-levels of challenge*; the overall satisfaction means of PYRAMID was 3.49. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on PYRAMID; • "It was a bit confusing."	- PYRAMID gradually moves on from an easier to a harder level. First level just introduces colours of each food groups. Different food pictures of different food groups are added in later levels. The higher levels which are harder will provide obstacles for children who can have progression, the harder level the more obstacles come up for challenging children.	- The feature of multi-levels would be applied to FoodGroups-A. It would gradually move on from an easier to a harder level. Easier level would provide basic knowledge for children to apply for playing harder levels. - Also, the higher levels which are harder would have obstacles to challenge children to play, and	- FoodGroups-B would be a no-level game.

Analysed data	Extracted features	Features in FoodGroups-A	Features in FoodGroups-B
	- However, some children did not know how to beat the confusing obstacles.	children would be provided with instructions of how to remove the obstacles.	
- **S16Py:** In terms of *being a relaxing game*; the overall satisfaction means of PYRAMID was 3.49. - There were no significant differences at all with respect to any of the four demographic variables of children. - Children's comments on PYRAMID; • "I liked this game because it was fun." • "The easy levels were far too easy such as 2nd level of the game just told about foods like apple or pudding. Whereas the higher levels were harder and gave less time, I preferred more relaxing games."	- PYRAMID is a game which has challenging obstacles. Children felt challenged to beat the obstacles. They agreed that they could play the game in a relaxing way, free from pressure such as time limit. - However, the previous levels were far too easy such as providing a few and simple foods for playing matching. Whereas the later levels were very harder because there were confused obstacles in which children did not know how to get rid of them, and less time to beat them.	- To make FoodGroups-A being immersed, appropriate pressure would be provided, such as obstacles, penalty score. In this way, children can play the game in a relaxing way.	- FoodGroups-B would have pressure more than FoodGroups-A in terms of their amount, speed, and time.

4.2.4.2 Important Features

Table 4.9 shows the detail of extracted features from the four existing games. From the analysis, the important features can be summarized into main eight features as Table 4.10.

Table 4.10 Important features from the Pilot Study.

Important Features
A DEG should provide a goal before starting the game. It should make children aged 7-11 years aware of the main goal of the game. Importantly, it should be clear enough in order to motivate children to reach the goal.
Children aged 7-11 years can start playing a DEG on their own when a simple instruction is given early. They tend to ignore a long text instruction. A help link providing more detail of what to do to get the right answer or to win the game, and how to overcome obstacles is also needed.
A DEG should be designed to allow different styles of playing. Gender preference should be considered to make suitable graphics/animation effects for both genders. Different genders have different preferences.
Children feel relaxed when gameplay is not difficult to be controlled. The DEG might have appropriate pressures such as penalty scores, speedy objects, overcoming obstacles. Also, it can be completed in a short time. Thus, a DEG for children aged 7-11 years should be relaxing to play. It should have minimalistic interfaces, appropriate speed, and no time pressure in order to promote fun and relaxation.
A game without any level is not preferred by most of the children aged 7-11 years. They enjoy multi-level games. A DEG should be separated into multi-levels. The multi-levels games gradually increase the level of challenge through the levels of game. The lower levels should provide essential prerequisite information for playing higher levels. It can be said that Initial levels of a DEG are disguised tutorials.
Different learning strategies, such as cues or signals strategy, should be provided to DEGs to deliver learning material rather than just present information.

Important Features
Rather than imitated-real or human-like pictures/graphics/animations, children prefer more on cartoon-like characters and their exaggerated animated actions such as angry monster is burnt when the decision is wrong, a food which comes in and go out in swerving way. Cartoon-like animations should be included to enhance imagination and fun.
Children need to know suddenly what they are doing is right or wrong, it make them assure the goal of the game and also know how far to win the game. A DEG needs to provide in-game feedback such as sound effects, rewards and scores to inform children aged 7-11 years about their progress.

4.3 Discussions

PH is conventionally used as an *analytic* tool for evaluating the playability of games. However, the results from the study shows that apart from the traditional use, PH; GameFlow model; could be used for interaction design of DEGs. Instead of using the set of usability principles which comes from experts' recommendations and usually used by evaluators who are experts to find usability problems in games, children could use a set of statements derived from GameFlow model to extract preferable features in games. Eventually, the preferable features could be formulated into checklists of design principles of DEGs.

However, it could be discussed that the reduced GameFlow statements should be fully functional to use for extracting the powerful game features if all criteria have been considered and interpreted in the right way. If not, it would have an effect on the features extracted which might be not functional enough. Moreover, the comprehension of the statements should be taken into account precisely to cover the literacy of all ages in the range of 7-11 years. Thus, the process of deriving the statements should be reliable and certifiable by groups of experts which might be the limitation of this research study (detailed of the limitation in Chapter 9; Section 9.2.2).

Another discussion is it might be skeptical to extract the most or the least preferable features by their means. Some feature, such as text style, was preferred in common all those games, so the means of the feature among those games were close. The highest mean was very close to the lowest one. Thus, the ambiguity might affect to upcoming heuristics which would be formulated from the important features extracted

(Chapter 5). Moreover, it would affect to the forthcoming two DEG on food groups which were created by synthesising the extracted features as well as followed the proposed heuristics (Chapter 6).

4.4 Conclusion & Outlook

This chapter illustrates how to use *PH*, which are typically used by experts for usability inspection, as a design tool. GameFlow model was adapted to be a contribution for this study. Specifically, the heuristics have been translated into a set of simple statements, which are understandable for children aged 7-11 years old. Further, the statements were compiled into an online questionnaire and integrated it into four existing game prototypes on food and nutrition, which were used to identify preferable and less preferable game features. In conclusion, I could offer the reduced GameFlow statements for children as a contribution for identifying preferable as well as less preferable game features.

Furthermore, the need for a specific set of heuristics for designing DEGs for this specific age-group was identified. In the next chapter, I aim to develop an alternative set of design heuristic for DEG for children aged 7-11 years. Then, systematic evaluations of the two new games enable the research to develop a robust game design reference model for digital educational games on the important topic of nutrition.

Chapter 5: Developing Design Heuristics

This chapter describes how the first version of the eight heuristics of DEG-7-11 has been derived.

5.1 Background

In the Pilot Study (Khanana & Law, 2013) (Chapter 4), a set of PH called *GameFlow model* (Sweetser & Wyeth, 2005) was adapted to investigate which game features of the four existing DEGs on nutrition children perceived to be most preferable and less preferable. Results of the Pilot Study enabled me to derive requirements for a new and improved DEG on food groups and to show that PH, apart from their conventional use for game evaluation, can be an effective means for game design. However, the results indicated that the PH used are not well suited for designing DEGs for school children aged 7-11 years. For example, the PH state broadly that games should be sufficiently challenging. Moreover, general PH focus on entertainment games rather than educational games. They are also normally used for evaluating rather than designing games. Hence, the need to develop an alternative set of PH to bridge this gap was identified.

Overall, the goal of this study is to analytically and empirically develop a set of heuristics that can inform the design of DEGs for children aged 7-11 years to learn a topic of interest effectively and enjoyably, which I refer to as DEG-7-11 v1.

5.2 Theoretical Background

5.2.1 Children's characteristics and learning style in the design of games

To maximise the acceptance of the game, it is important to take into account children's requirements. Thus, before starting to design a game, characteristics and learning style of children aged 7-11 years old and their need should be understood. There are a wide range of criteria defined in the literature on these variables. Markopoulos et al. (2008) pointed out that different children (e.g. gender, age, and learning style) require distinct sets of game requirements. The following points should be addressed when designing games: provision of appropriate rewards and punishments, short concentration span of young children, sensitivity of task performance to factors

such as time constraint, clarity of instructions, feedback on progress, task of appropriate complexity and size, and gender-specific preference for game characters. They observe that school children have a concentration span for about 30 minutes. A child spends a shorter period of time on a difficult task. Children most probably give up a product, which is not easy to learn to how to use or not easy to reach a certain level of competence. It can be said that they may give up hard task easily. Instructions must be very clear, possibly with the use of technology. Clear and timely information of their progression should be provided. Children's tasks should not be complicated and small enough to be remembered. It is usually enough to have one task at a time. Reminders about the task are needed for many children. The order of items or their appearance can affect children's responses. In the real world, some children do not perform well when working under the time pressure. If a game starts off with an easy level and gradually moves to a harder level, it may then be a good teaching tool. Another characteristic for a properly designed game is that each level in a game is hard enough to be a trial, but still allows the player to complete it. It can be said that the game is simultaneously delightful and challenging. The game can attract players to continue playing repeatedly, even after failure, in order to get better at the game. It can be clear that the more levels a child plays the game, the more the game content he or she can see.

5.2.2 Theoretical Interdisciplinary Knowledge for Developing Design Heuristics

5.2.2.1 Psychology

(i) Goal Setting

A goal is the object or aim of an action or task that a person desires to obtain usually within a specified time limit. A goal is the source of motivation that a person intends to reach. Locke and Latham (2002) proposed the role of goals as mediators of incentives. Setting a goal right can improve performance. People become motivated to increase effort if they find that their current effort is not achieving desired goals. They found that specific, difficult goals led to higher performance than letting people do their best. Also, it can enhance students' motivation to learn. The event 2 of Gagné's instructional event (Driscoll, 2005) - "informing the learner of the objective" implies that expectancy on what is to learn influences how learners are aware of and prepare themselves to learn certain information. Clement (1961) stated that making students conscious of the learning goal could enhance their learning success.

Goals are separated into two classes: (1) learning goals, children attempt to increase their efficacy, to understand or master something new, and (2) performance goals, children attempt to gain favorable judgments or avoid negative judgments of their efficacy (Elliott & Dweck, 1988; Nicholls, 1984). The different goals can either facilitate or block children's cognitive performance. With a performance goal, children who are confident in their ability need to maintain high level of confidence to sustain task involvement, however, it is difficult to maintain that level of confidence. If children attribute failures to a lack of ability, this tends to result in defensive withdrawal of effort to deal with obstacles. In contrast, children with learning goals tend to use obstacles as a cue to increase their effort or to analyze and vary their strategies, which often results in improving performance to deal with obstacles. That is, the more children focus on learning or progress, the more they apply effective strategies to cover difficulty or failure. Performance goals are found to undermine intrinsic interest such as task interest or enjoyment. That is, effort to face uncertainty appears to be disinterested for children. For a learning goal, children's satisfaction with outcomes is based on the effort they have spent in pursuing the goal, whereas for performance goal, children's satisfaction with outcomes is based on the ability they believe they have displayed (Dweck, 1986).

Being ignorant of the main goal of a game can lead to confusion and thus poor performance. However, children tend to ignore instructions given in a game as they are eager to play it (Law & Sun, 2012). Pagulayan et al. (2003) suggest that the goals of a game should be conveyed clearly and in a straightforward manner. Hence, the mission of a game should be described briefly.

(ii) Memory

Not only scientists research on how to enhance memory, but also educators give the high importance to the role of memory in the learning process. From the point of view of educators, memory is one of the significant indicators that something has been learned. Attending to learning material, assimilating and accommodating new knowledge, constructing meaning or demonstrating their learning, all of this requires memory (Banikowski & Mehring, 1999). Thus, the theory to enhance memory has been studied and applied in designing DEGs.

A working memory or short-term memory is primary memory for temporarily holding component for new information and manipulating information as part of

cognitive tasks: learning, reasoning and comprehending (Baddeley, 1997). It is restricted in volume and length of time. The memory is weak and easy to lose. Giving too much information and too rapidly is ineffective. Thus, chunking information can overcome the limitation of short-term memory. Chunked information as a little single unit requires less space of memory than overall individual information. Gagné and Briggs (1974) also stated that information must be presented in purposive chunks so that learners do not overload their processing system. Then, making the association between chunked information helps to transfer the information from short-term to long-term memory. Gagné proposed that new information had to be associated with previously learned and related ideas, making it conducive to be recalled (Driscoll, 2005). To retain the information, learners must keep repeating the information in their mind. Learners must keep activating the information by rehearsal. *Practicing* can help learners to process information automatically.

Chunking a game into multi-levels can induce young school people who do not prefer short and easy games as Gee (2005) asserted. In addition, Gee (2005) pointed out that a multi-level game each level could be utilized to gradually deliver content to learners and that problems needed to be presented orderly; strategies for solving primary problems could be generalized to the subsequent problems. In the study reported in (Downes, 2009), children described how they could get better at games after the initial learning period. Some children mentioned that they were conscious how earlier learning experiences could alter their responses to different learning situations encountered subsequently.

(iii) Cued recall

Learners absorb and retain material and knowledge better when various instructional strategies, models or situations are provided (St-Pierre, 2011). Information which is given more attention is more likely to remember than the information which is disregarded (Sternberg, 2008). Strategies to gain student's attention were reviewed in order to support the game design. For example, cues or signals strategy is effective in assisting students to pay attention (Banikowski & Mehring, 1999). Markopoulos et al. (2008) pointed out many children need reminders about the task they are doing. According to Gagné's principle of "stimulating recall of prior learning", it is necessary to enable learners to recall prerequisite knowledge for solving new problems. There should have clues which children have to keep in their head, then they can get better at

games after the initial learning period (Downes, 2009).

Cued recall is the retrieval of memory with the help of cues (Moult, 2011). Cues perform as pointers to what the person is assumed to remember. A cue can be practically anything that may perform as a reminder (e.g., smell, song, colour, and place). Dual Coding Theory (DCT) can be applied to cued recall. Clark and Paivio (1991) hypothesized the theory of basic psychological mechanisms that can be used to model diverse educational phenomena; it is Dual Coding Theory (DCT). They supposed that in long-term memory, information is retained in two forms; visual and verbal. They argued that the information is recalled well if it is represented in both forms.

Accordingly, visual and verbal stimuli can be associated to represent information, to set learning goal, and to enhance comprehension and memory performance.

(iv) Emotion

Emotion is proved to play a role in learning efficacy. Rolls (2005) defines that emotion constitutes cognition. Forgas, Burnham, and Trimboli (1988) indicated that the motivational consequences of moods were important for children's cognition. Piaget posited that three aspects of development - cognitive, emotional, and moral - evolve in parallel in stages, and that children in the concrete operational stage (aged 7-11 years) become less and less egocentric (Hesse & Cicchetti, 1982; Hourcade, 2008; Piaget, 1973). Iskander, Kapila, and Karim (2010) also stated that cognitive, social and emotional development cannot be considered in isolation. Either positive or negative emotion may obstruct or support mastery level (Brand, Reimer, & Opwis, 2007). Happy moods motivate more efficient information-processing in children, whereas sad moods cause the children to become more withdrawn and inattentive. Happy moods have positive effect on memory; happy children learn and remember better.

Several research studies (e.g., Ryan, Rigby, & Przybylski, 2006; Russoniello, O'Brien, & Parks, 2009) show that playing games can promote relaxation, especially games with minimalistic interfaces, short-term commitments, and a high degree of accessibility, e.g. Angry Birds, Bejeweled II (Granic, Lobel, & Engels, 2014). Russoniello, O'Brien, et al. (2009) supported that the relaxing games like Bejewled II can decrease stress and increase efficiency in positive cognitive engagement. Markopoulos et al. (2008) observed that children have a concentration span of about 30

minutes. Thus, a sense of relaxation should be created.

Relaxation is the emotional state of a living being of low tension. There is also evidence that mental relaxation might enhance memory performance (Nava, Landau, Brody, Linder, & Schächinger, 2004).

(v) Rewards and punishments

As the importance of emotion mentioned above, while the notion of regulating behavioral responses can be dated back to the psychological theory of Skinner (1953), theories of cognition and emotion (e.g., Ortony, 1990) are regarded as more relevant to understand the psychological mechanisms. Emotions can be evoked by incorporating the concepts of drive and motivation like rewards and punishers (Rolls, 2005). Issuing reward and punishment contingent on a player's action is one of the critical game elements that sustain the player's motivation to engage in the game (Sweetser & Wyeth, 2005). Specifically, rewards and even punishments in a game setting, when delivered in timely and engaging manner, can lead to positive emotions (e.g., fun, pleasure, enjoyment, surprise, stimulation, excitement, proud) and other beneficial effects (Wang & Sun, 2011).

Piaget argued for the importance of intrinsically motivated play-like activities for many kinds of deep learning (Malone, 1981). Protopsaltis et al. (2010), in discussing innovative methodological approaches to digital educational games for creative learning, argued that motivation can be sustained through methods such as feedback, reflection, and active involvement. Gagné considered that one of the conditions for learning cognitive strategies is informative feedback (Driscoll, 2005). Feedback is important for players' learning and satisfaction with the game (Pagulayan, et al., 2003). Without feedback it can be hard to determine the progress towards objectives. Markopoulos et al. (2008) also argued that the information on progress should be shown to players about their achievement. Without such feedback, it would be difficult for players to adjust their effort for reaching the goal effectively (Sorrentino, 2006).

5.2.2.2 Pedagogy

(i) Guidance or instructional support

Piaget stressed the value of independent as well as guided inquiry, the implication for the design of a DEG is to enable children to explore it themselves

(Jacob, 1984). Participants need guidance to understand the principles of a learning technology (Rieber & Rieber, 2005). Training and guidance are useful for novice players because they use a lot of time for learning to play a game (Virvou & Katsionis, 2008). Inadequate directions is one of various problems of many computer games identified by Gredler (2004). Game designers need to recognize the problem of how to help players play games more easily and effectively. Such improvement may effect on students' learning.

Different types of instructional support in games that might enhance learning are proposed by many researchers (Swaak & De Jong, 2001). Any types of assistance to help students learn are considered as instructional support (Tobias, 1982). Explanations, feedback, help, modeling, scaffolding, fading the steps, worked examples, and procedural direction are included as guidance (Tobias & Duffy, 2009). "Worked examples" is recommended to use for facilitating learning (Kirschner, Sweller, & Clark, 2006; Renkl, 2005; Tobias & Duffy, 2009). Fading the steps (i.e. gradually decrease the instructional support) for such examples gradually increase transfer (Renkl & Atkinson, 2003). Apparently, those forms of instructional supports in games are important to enhance learning (Tobias & Fletcher, 2011).

A form of providing guidance by explaining the reasons of correct answers may be more useful than only relying on the games (Moreno & Mayer, 2005; Swaak & De Jong, 2001). According to Gagné, meaningful learning guidance should help learners find the required information and include examples (Driscoll, 2005).

Not only the forms of instructional support in game but also the frequency of using it is important for players' learning. As students often do not use help functions in interactive learning environments very effectively or even ignore them totally (Aleven, Stahl, Schworm, Fischer, & Wallace, 2003). Consequently, the instructional supports provided do not foster learning outcomes as expected (Wittwer & Renkl, 2008). Guidance is found to be infrequently used when available and does not increase learning (Nelson, 2007). As mentioned by Cornett (2004), players are easily annoyed by a lengthy, complex and over-emphasized manual. Children aged 7-11 tend to ignore text-based instructions (Law & Sun, 2012). A game heuristic developed by Desurvire and Wiberg (2009) also specifies that a manual should be interesting and mimic gameplay. DEG are recommended to incorporate instructional supports into games and to present them in multimodal formats whenever possible (Tobias & Fletcher, 2007).

5.2.2.3 Design

(i) Gender-Based Adaptation

The awareness of gender specificities and gender sensitivity in the game sector is increasing. It is an important step in creating digital games to meet players' special needs. Creating DEGs that are enjoyable and desirable for players of different ages, genders and other characteristics is challenging. A novel approach to learning should benefit learners of both genders (Boyle & Connolly, 2009). Hence, gender-based adaptation framework on a DEG development has been proposed by Steiner, Kickmeier-Rust, and Albert (2009). The framework especially suites and is needed in the context of DEGs, where a DEG should support learning for all students with equal opportunities. Otherwise, players may mistakenly perceive that the game is not created for them and reject it. Accordingly, different game features, components, and characteristics can be chosen for female or male players. These adaptation variables are derived from the literature. One of main variables is *Game Characters and Avatar Preferences*; players should have the chance to select or create their own favorite avatar. It can not only enhance students' motivation and learning performance, but also can improve cost-effectiveness of game development – one game can be adapted for both genders instead of different games developed for male and female players.

(ii) Animation

In educational context, animation is being used effectively to facilitate comprehension or understanding. Popular profit of animation is to depict unperceived things to be visualized explicitly (Tsung-Yen & Wei, 2007), for example, the blood circulation in human body. Especially, such things would be simple and easy enough for children to understand.

Animation is further used in playful learning. It is engaging for children to play and learn at the same time (Scaife & Rogers, 2005). Children tend to interact more frequently with the educational software which has animated interface rather than static images (Tsung-Yen & Wei, 2007). Animated versions of a learning agent are more engaging and reliable than static images versions.

Moreover, animation can be utilized effectively to design virtual characters. However, animations should be symbolic and simplified and away from the realistic (Tversky, Morrison, & Betrancourt, 2002). Children up to 12 years old may prefer more

cartoon-like characters than human-like ones (Lowe & Schnotz, 2008). They are much familiar with the cartoon-style of animation shown on TV, video games and comics, and understand the expressions of cartoon-like characters (Scaife & Rogers, 2001). Film industry uses the technique of developing simple animations with exaggerated expressions and behaviors. Children can learn easily through their exaggerated animated actions and behaviors such as mood, emotion, action. They can use their imagination and creativity to interpret in playful learning. As it is fun to have imagination, it can be inferred that animations can help children learn better (Ainsworth, 2008).

5.3 Research study

In this chapter the main contribution was a first version of new set of DEG design heuristics, called DEG-7-11 v1, developed based on the game features empirically identified from the Pilot Study (Chapter 4) and on the theoretical frameworks systematically analysed.

5.3.1 Apparatus

The heuristics have been developed based on three sources: (i) the results of the Pilot Study, (ii) existing playability heuristics, which are insufficient for DEGs, leaving gaps to be addressed and (iii) literature reviews of selected theoretical frameworks from three relevant disciplines – psychology, pedagogy and design. Each of the three sources is described in the following.

5.3.2 Method

5.3.2.1 Pilot Study

The contribution of the Pilot Study was to provide a set of powerful features which are important for designing DEGs for children aged 7-11 years. Playability heuristics (PH), the GameFlow model, was adopted and adapted as an empirical tool to elicit such game features. A specific questionnaire was developed as follows: First, the criteria of the elements of the GameFlow model were identified. Then those criteria were mapped to the features of four existing web-based games on nutrition to be played by the study's children. Next the criteria were translated into a set of 28 simple statements understandable to children. Finally, the statements were compiled as a

questionnaire, which was integrated into the four games. The games contain similar educational content about food groups and healthy eating habits, but they have different game components such as visual presentation, interaction technique, and reward/punishment format. For example, one of the four games is one-level game and the others are multi-level. Among the three multi-level games, two provide information included in the lower levels to enable children to deal with the tasks in the higher levels. One of the games, children need to beat the time to win the game. All four games apply different animation styles one of them applies human-like characters, whereas others apply cartoon-like characters. Also, all four games have different feedback interfaces and present information mainly in the textual format.

One hundred children aged 7-11 years were involved in the Pilot Study. Children were asked to play the four games on an individual basis. Based on their gameplay experiences, they were asked to rate each of the 28 statements with a visual analogue scale (Shields, Palermo, Powers, Grewe, & Smith, 2003) (details are reported in Chapter 4). Finally, a set of important features for designing DEGs for children aged 7-11 years was found (Section 4.2.4.2, Table 4.10).

5.3.2.2 Gaps of Existing Heuristics

In the Pilot Study how Playability Heuristics (PH), which are typically used for usability inspection, has been used as a design tool for a DEG was reported. While the reviewed heuristics focus on different aspects of game design, a consolidated set could be useful. Sweetser and Wyeth (2005) integrated different heuristics into a concise and validated model known as GameFlow, which is structured by the flow theory (Csikszentmihalyi, 1990). The model comprises a set of elements and associated criteria that can be used to evaluate and understand enjoyment in games. Given its comprehensibility, the GameFlow framework was adopted in this research project to design a DEG for children aged between 7 and 11. However, the results indicated that the PH and associated criteria are generic, not well-suited for designing DEGs, especially for children aged between 7 and 11. Its gaps were indicated in (Table 5.1). Nonetheless, in developing an augmented set of heuristics to bridge the gaps identified, I referred to the GameFlow model to illustrate how the proposed heuristics can address individual gaps.

5.3.2.3 Theoretical Frameworks

Regarding to the gaps of the GameFlow model, and the extracted preferable and less preferable game features, as evaluated by the children in the Pilot Study, they were further substantiated by theoretical frameworks from three disciplines – psychology, pedagogy and design as reviewed in Section 5.2.2. Consequently, a first version set of heuristics known as DEG-7-11 v1 have been developed.

Table 5.1 shows the findings of the Pilot Study, gaps of the GameFlow, and the list of theoretical frameworks contributing to the development of the DEG-7-11 v1 heuristics.

Table 5.1 Important features from the Pilot Study, Gaps of GameFlow model, and Theoretical Frameworks are derived to DEG-7-11 v1 elements

GameFlow Elements	**Important features from the Pilot Study**	**Gaps of the GameFlow**	**Theoretical Frameworks**	**Proposed heuristics for DEG-7-11 v1** (detailed in Section 5.3.3.1)
Clear goal	Goals should be clear, concise, simple, and presented early in a game (detailed in Table 4.10).	The GameFlow suggests that games must have an objective or goal and the goals must be clear. However, it should have put more emphasis that goals need to be specific and clear when presenting to players.	A learning goal is suitable for children's learning (detailed in "Goal Setting", Section (i)).	DEG-7-11#1
Player skill	Instruction should be given early in a game and explain how to get a right answer, but should not rely on text-based manual only (detailed in Table 4.10).	The GameFlow suggests that players should have adequate information to start playing game. Players should be taught how to play the games. However, for a DEG, not only how to play the game should be taught, but also specific feature of instructions should be explained, such as an example of how to get a correct answer in order to support children to learn rather than let them play by trial and error only.	Guidance or instructional support should explain how to get correct answers (detailed in "Guidance or instructional support", Section (i)).	DEG-7-11#2
Control	A game should suit different genders (detailed in Table 4.10).	Games should be designed to allow different styles of learning and playing, it is suggested by the GameFlow. However, which key factors contributing to such differences in learning style are not specified.	One of the key factors contributing to differences in learning style is gender. Gender difference should be addressed. Children should be able to select or create their own favourite avatar	DEG-7-11#3

GameFlow Elements	Important features from the Pilot Study	Gaps of the GameFlow	Theoretical Frameworks	Proposed heuristics for DEG-7-11 v1 (detailed in Section 5.3.3.1)
			according to their gender. Gender-based adaptation framework, especially Game Characters and Avatar Preferences should be addressed (detailed in "Gender-Based Adaptation", Section (i)).	
Immersion	A DEG for children should have minimalistic interfaces, appropriate speed, and no time pressure in order to promote fun and relaxation (detailed in Table 4.10).	Games should help people to calm down after a hard day or to escape from everyday worries. However, what game features which make players relaxed while playing should be specified.	Games should have features of relaxation to play by having minimalistic interfaces, appropriate speed, and no time pressure. They can promote relaxation while playing (detailed in "Emotion", Section (iv)).	DEG-7-11#4
Challenge	A DEG should be separated into multi-levels. Initial levels of the DEG should be disguised tutorials (detailed in Table 4.10).	Games should provide different levels of challenge. The levels of challenge increase as the players progresses through the games and increase their skill level. That is the good point of the GameFlow which should be exploited for designing a DEG such as previous levels should be used to be disguised tutorials for next levels.	Principles of chunking, associating and practicing should be utilized to the design of a multi-levels game (detailed in "Memory", Section (ii)).	DEG-7-11#5
Concentration	Cartoon-like animations should be included to enhance imagination and fun (detailed in Table 4.10).	Games should be visually appealing, with interesting character models. However, what kind of character models suit children need to be specified in case of DEGs for children.	Cartoon-like animations are much familiar to children and their expressions are more understandable to children. They enable playful learning (detailed in "Animation", Section (ii)).	DEG-7-11#6
Feedback	Feedback can inform children about their progress (detailed in Table 4.10).	The GameFlow raises the importance of in-game feedback. In-game feedback is necessary for players to determine their progress. Specific features of feedback like reward and punishment is valuable for designers to design DEGs.	Rewards and punishments should be provided in the form of in-game feedback interfaces (detailed in "Rewards and punishments", Section (v)).	DEG-7-11#7
-	A game should incorporate reminders or hints to children (detailed in Table 4.10).	-	A game should incorporate reminders or hints to children (detailed in "Cued recall", Section (iii)).	DEG-7-11#8

5.3.3 Results and Discussions

5.3.3.1 Descriptions of DEG-7-11 v1

Finally, as shown in Figure 3.3 (Chapter 3), a set of eight DEG-7-11 v1 heuristics has been derived and then validated. Each DEG-7-11 v1 heuristic is elaborated as follows:

DEG-7-11#1: Instead of setting a goal on performance, such as scoring, like entertainment games, for a DEG, a specific learning goal should be set. Also, the goal should be clear, concise, simple, and presented early in the DEG.

Knowing the goal of the game is important. The goal of a game plays a key role in guiding a child to learn in different instructional conditions and events (i.e., Gagné's learning theory). Children need to know the main goal in order to prepare themselves to complete the game; it is thus recommended that the main goal of the game should be presented before the game is started. Moreover, in order to reduce the risk of instructions being ignored by children, it is crucial to make the goal clear, concise, and simple.

Importantly, specific types of goal are recommended. With performance goals, the task choice and attainment process focus on children's ability whereas with learning goals the task and process focus on children's effort (Dweck, 1986). When oriented toward performance goals, children who judge themselves to have low ability, are often found to choose easy tasks for which success is ensured. In contrast, children with learning goals tend to choose challenging tasks regardless of whether they believe themselves to have high or low ability. Hence, children should be given the learning goal rather than the performance goal in a DEG. To develop new competence in children, they should have chance to go through a failure (Dweck, 1986). They should develop a sense of achievement by learning rather than just by winning while playing. Thus, a DEG should not only motivate children to beat the highest score but also enable them to understand new learning material.

Conclusively, instructions should make children understand the main goal of the game before playing it. The main goal should be a learning goal which is clear, concise and simple.

DEG-7-11#2: Children aged 7-11 should be supported by instructions when playing a DEG; the instruction should explain how to get correct answers, but without relying on text-based manual only.

Children may be able to learn independently if they are provided with some simple and easy to follow guidelines. Such guidance is typically presented as help-text or an instructional manual. Children aged 7-11 should be supported when playing a DEG. They often need information how to proceed with gameplay. Some instructions are needed to enable players to understand the game. There are various forms of proposed instructional support (Swaak & De Jong, 2001). It is more useful to provide different types of assistance to help children learn. In the context of gaming, learning guidance can be realized as providing a player with information about how to get correct answer. Nonetheless, one should not rely on text-based instructions which tend to be ignored by children (Law & Sun, 2012) and a lengthy, complex and over-emphasized manual are annoyed by them (Cornett, 2004), but consider using different modalities such as audio-visual instructions as Desurvire and Wiberg (2009) recommended that a manual should be interesting and mimic gameplay. Mixed-modality guidance with image, animation, sound or video is preferable for children aged 7-11 (Tobias & Fletcher, 2007).

To sum up, DEG designers are recommended to incorporate instructional supports into games and to present them in multimodal formats whenever possible as well as to explain how to get correct answers.

DEG-7-11#3: One single DEG could suit different genders so that children can select or create their own favourite avatar.

Sun and Law (2010) found that gender is one important factor which drives children to intend to play DEGs. The understanding of the driving factor can assist game developers to design a DEG to support learning both genders. Although developing a DEG which appeals both males and females requires an additional level of complexity and complicated process, a game, be it a DEG or of other types, should aim to be gender neutral and should be designed without a gender bias (Boyle & Connolly, 2009). Steiner, et al. (2009) proposed gender-based adaptation framework which is needed in the context of designing DEGs, designers should consider gender differences (e.g., preference for game characters or avatars). One of the adaptation variables is

avatar preferences. Most players prefer avatars of the same gender; males prefer powerful fighter avatars, whereas females prefer fashioned and beautiful characters. It is recommendable that players should be given options to select or even create their favourite avatar.

If children can adapt the game to fit their preferences and tastes, it can reach out to both girls and boys. Otherwise, children may mistakenly perceive that the game is not created for them and reject it.

DEG-7-11#4: A DEG for children aged 7-11 years should be relaxing to play by having minimalistic interfaces, appropriate speed, and no time pressure.

Based on the understanding of the work of Jean Piaget (Piaget, 1973; see also the review in Hourcade, 2008) and other scholars (e.g., Hesse & Cicchetti, 1982; Iskander, et al., 2010), it is convinced that the cognitive and emotional development of children aged 7-11 entail specific design strategies and approaches.

Markopoulos, et al. (2008) mentioned that the more a game's content can be seen by a child, the more levels should be provided for him or her to play. The game should attract players to play repeatedly, even after failure, in order to get better at the game. A DEG is likely to involve long gameplay because repetitive tasks are required to enable children to practise as much as possible. Thus, to enable children aged 7-11 years to sustain playing a DEG for a longer period of time, the game should create a sense of relaxation in players rather than always putting them under time pressure as most non-educational games do. Several research studies (see Section (iv)) show that games with minimalistic interfaces, short-term commitments, and a high degree of accessibility can promote relaxation in players. The relaxing games can decrease stress and increase efficiency in positive cognitive engagement.

DEG-7-11#5: A DEG should be separated into multi-levels with initial levels being disguised tutorials, enabling children to practise new information by performing similar tasks.

Memory plays an important role in cognition. However, working/short-term memory is weak and easy to lose. New information should be presented increasingly at a pace to address the limitation of short-term memory of learners (Banikowski & Mehring, 1999). Hence, a game should be chunked into levels to be presented in different screens. Maintaining chunked information in working memory may facilitate a

learner to transfer it across levels (Gagne & Briggs, 1974; Markopoulos, et al., 2008). The associating information helps transfer the information from short-term to long-term memory. New information must be related to what learners already know on the one hand, and have distinctive features on the other hand to draw the learners' attention. A variety of examples are needed to promote transfer by practicing (Banikowski & Mehring, 1999).

Based on the above review (Section (ii)), it can be argued that a game without 'preparation level' is not suitable as a DEG for children, because it has no progressive levels to provide the related content in a stepwise manner. Above all, the implication of the principles of chunking, associating and practising for the design of a DEG is to separate game into multi-levels and to associate each level by providing hints linked to previous levels, as well as to let children play repeatedly, enabling them to develop a better understanding of the information and securing their knowledge into long-term memory.

DEG-7-11#6: A game should incorporate reminders that children can use for recalling information from their memory.

Apart from the strategy of chunking, associating and repeating information (DEG-7-11#5), helping players build up background knowledge in lower levels can facilitate them to resolve challenges in higher levels (Downes, 2009). A meaningful context must be provided for effective encoding of information, such as using techniques of imagery. Cued recall, one kind of instructional design strategies can be applied for enhancing memory. Cues or signals should be included in the instruction to remind learners of the conceptual basis for the rule. Cues are also used to gain learners' attention (Banikowski & Mehring, 1999). A cue can be practically anything that may perform as a reminder (Clark & Paivio, 1991). In this study to be reported later, colours were used as a cue to remember the different groups of food.

DEG-7-11#7: Animations can influence learning for children aged 7-11 years, especially cartoon-like animations can enhance imagination and fun, resulting in playful learning.

The role of animation is increasing significant in educational context as described in Section (ii), such as use to design virtual characters, use to depict unperceived things to be visualized explicitly. In playful learning, animated versions of

an educational software is more charming and attractive for children than static images versions (Scaife & Rogers, 2005; Tsung-Yen & Wei, 2007). It is important to illustrate the game world and the interactions between game characters therein by using animations.

Especially for children aged 7-11 years, using cartoon-like characters can have more effective result than using human-like characters (Ainsworth, 2008). Children are familiar and prefer more exaggerated expressions and behaviors of cartoon-like characters than realistic expressions of human-like ones (Lowe & Schnotz, 2008; Scaife & Rogers, 2001; Tversky, et al., 2002). They can interpret creatively and learn joyful through the overactive animated actions.

DEG-7-11#8: Rewards and punishments should be provided in the form of in-game feedback interfaces; they are incentives and can inform children aged 7-11 years about their progress and learning.

One of the critical game elements that lead to positive emotions and sustain the player's motivation to engage in the game is reward and punishment (Rolls, 2005; Sweetser & Wyeth, 2005; Wang & Sun, 2011). Specifically, rewards and punishments when delivered in timely and engaging manner such as delivered through feedback, not only the motivation can be sustained (Protopsaltis, et al., 2010), it also can lead to other beneficial effects such as ability of determining the progress towards objectives (Pagulayan, et al., 2003; Sorrentino, 2006). To enable players to be aware of their own progress, there are various ways of offering in-game feedback. For instance, if scores and pleasant sound effects are presented each time a child performs an appropriate action leading to a learning goal, she is then encouraged to carry out a similar action in the future.

5.3.3.2 Types of DEG-7-11 v1

DEG-7-11 v1 consists of two types of heuristics: two essential heuristics and six recommendable heuristics (Table 5.2). Based on the empirical results of the Pilot Study and on the literature review indicating the critical role of learning goal and instructional supports (Section 5.2.2), the *essential heuristics* are assumed to be necessary in DEGs. To play a DEG, children should know a learning goal in order to discover the effective strategies to attain the goal (DEG-7-11#1). To explore a DEG independently, the goal and adequate direction should be described clearly in the instructive instruction

provided (DEG-7-11#2). It would say that without a learning goal and instructive instruction (essential heuristics), the game would not be playable. In addition to the playable properties, a DEG might elicit better gameplay experience, game usability, and learning effectiveness if *recommendable heuristics* are followed.

Table 5.2 Types of DEG-7-11 v1

	Essential heuristics		**Recommendable heuristics**					
DEG-7-11 v1	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**

5.4 Discussions

The results from the study argued that the set of PH called *GameFlow model* (Sweetser & Wyeth, 2005) is more effective to evaluate and understand enjoyment in general games rather than to design educational games. Although it can be applied to investigate preferable features in games, it contains some gaps needed to be bridged. The first version of DEG-7-11 was developed as an augmented PH set of the GameFlow.

5.5 Conclusion & Outlook

This chapter describes how the first version of DEG-7-11 has been developed analytically and empirically. Specifically, the results of the Pilot Study stimulated me to address the need for a set of augmented design heuristics for children aged 7-11 years as well as provided some empirical data to ground the new heuristics. The relevant theoretical frameworks of the three disciplines, as well as sort of gaps of other heuristics that should be bridged were reviewed. Two prototypes of DEG for teaching children aged 7-11 years about food groups have been developed. They are reported in Chapter 6. Then, a series of empirical validation studies have been conducted (Chapter 7). Results thereof provide further evidence whether the eight heuristics of DEG-7-11 v1 can effectively inform the design of educational games. It can be concluded that the GameFlow model is being augmented by DEG-7-11 v1.

Chapter 6: Games Design

This chapter describes how the eight heuristics of DEG-7-11 v1 have been implemented for designing two games.

6.1 Background

The findings of the Pilot Study showed that the selected four games might be enjoyable for children and could enhance their knowledge of nutrition. However, they are separated games which contain different preferable features. Hence, there is a need to synthesize these preferable features of the individual four games into an integrated game that can be a robust game design reference model for DEGs. Then, two games were developed by using a set of eight DEG-7-11 v1 heuristics which has been derived analytically and empirically. It is assumed that if a game is designed by following those heuristics, the game will enable children to learn a topic effectively and with fun.

Game Genre

The term "casual games" is not clear in definition, the previous studies on the area of casual games has not rigorous (Kuittinen, Kultima, Niemelä, & Paavilainen, 2007). Kuittinen, et al. (2007) discussed the various definitions determined by different organizations such as International Game Developers Association (IGDA), Casual Games Association (CGA), GDC Casual Games Summit (The Game Developers Conference). They eventually provided clarification of the meanings and certain properties of a casual game that is "casual games has generally appealing content, simple controls, easy-to learn gameplay, fast rewards, or support for short play sessions". IGDA (2008-2009) defined casual games as they are easy to learn to play and have simple controls, for example, using a simple mouse-click control. They can be played in 5 to 20 minutes. Casual games tend to give children fun and relaxation rather than the commitment required for more complex games. They require no long-term time commitment or special skills to play. They guide children through the first levels and gradually introduce them to more complex game play. Gerling, Fuchslocher, Schmidt, Krämer, and Masuch (2011) claimed that casual games are regarded as an easy way for people to start playing video games because of their simple gaming mechanisms in general.

Because of the simplistic nature, playing casual games is an increasingly favourite leisure activity among children and teenagers. Casual games become popular as educational games among children. Klopfer, Osterweil, and Salen (2009) supported that educational games do not need any expensive 3D graphics or multi-button controllers to build a much engaging experience. Parents and teachers concern about unfamiliarity with games and no easy route to game competence. The solution to these difficulties tend to be games which are easy to learn and can be played in very short bursts of class time. Thus, casual games which are simple and easy to grasp immediately become one of the fastest growing markets of educational games. They are typically played on a personal computer, not required any newest technology.

Given the aforementioned benefits of casual games, the genre of casual games has been adopted for developing two DEGs used for verifying the assumed benefits of DEG-7-11 v1 in this research project. One of the two games is called *FoodGroups-A* and the other is called *FoodGroups-B*. Both games are single user game. It can be played online or offline. It is run on Windows. Computers should have Flash Player for running the games.

6.2 Research study

The main contribution from this chapter was the two games.

6.2.1 Apparatus

6.2.1.1 Adaptation of the preferable as well as less preferable features from the Pilot Study

With the results of the Pilot Study, two DEG on food groups were developed based on the guiding of the preferable as well as less preferable extracted features from the selected games. Such features (detailed in Table 4.9) were adapted and synthesized to create FoodGroups-A and FoodGroups-B. FoodGroups-A was aimed to have the most preferable features from the four selected games whereas FoodGroups-B had the less preferable ones.

6.2.1.2 Implementation of DEG-7-11 v1

According to the two types of heuristics of DEG-7-11 v1: two essential heuristics and six recommendable heuristics (detailed in Section 5.3.3.2), for playable properties, both games provide *essential heuristics*; learning goals (DEG-7-11#1) and instructive instruction (DEG-7-11#2); in order to let children discovering the effective strategies to attain the goal and exploring the DEGs independently. In order to compare the quality of gameplay experience, game usability, and learning effectiveness of the two games, the *recommendable heuristics* are followed only by FoodGroups-A. Summary, FoodGroups-A was designed by following all the eight heuristics of DEG-7-11 v1, whereas FoodGroups-B followed the two essential heuristics but not followed the recommendable heuristics. (Table 6.1)

Table 6.1 The list of DEG-7-11 v1 inform to design two different DEGs

DEG-7-11 v1 GAME	Implementation							
	Essential heuristics		Recommendable heuristics					
	#1	#2	#3	#4	#5	#6	#7	#8
FoodGroups-A	√	√	√	√	√	√	√	√
FoodGroups-B	√	√	×	×	×	×	×	×

6.2.1.3 Technology for Designing and Developing the Games

As described above, the game aims to teach children about food groups. There are two versions of the game, FoodGroups-A and FoodGroups-B. Both have been developed by integrating sub-levels and online questionnaires. Their interfaces were created by Adobe Flash CS4. Their interactive functions were coded by Action Script 2.0&3.0. The data of questionnaires could be saved in MySql database by PHP.

(i) Flash

The demand for Flash development is increasing day by day. In the animation and games development sector, Flash gives designers the opportunity to use creativity to the fullest. Designers are comfortable in working with Flash. They can develop Flash

games of appropriate difficulty. An entire gameplay mechanic can be prototyped in a few hours.

Games incorporated with powerful graphics and innovative concepts can generate a lot of interest among the players. They can be different modes and levels and can be easily downloadable. Interactive visual artefacts can be incorporated in making games by Flash. PCs are not needed to install ActiveX controls or a Java plug-ins. Flash player is preinstalled with Windows on corporate machines. Flash also well supports the streaming technology. Players can start playing Flash games as soon as they finish downloadable games. Flash primarily uses vector graphics. This means that lots of unique graphics can be attached and the file size will remain relatively small. It also means that the graphics of games will scale depending on the user's screen size.

In terms of facility tool, the developer tools are strong and well supported. The Flash developer community is large and mature. There are thousands of Flash related web sites with tutorials, articles, and discussions.

In short, Flash is good for developing PC Web Games. In my research project, I use Flash to create game characters and animate them.

(ii) ActionScript

Actionscript is an object oriented scripting language. It is similar to the JavaScript programming language. Through the Actionscript code the developer can set and control the actions of the Flash objects.

ActionScript works best for animating applications interactive Flash games. It can provide visual and interactive effects. It is suitable for developing small web games. It uses Flash environment, so it doesn't matter which browser is used; the Flash platform is universal. If the audience is children, ActionScript is a proper choice.

ActionScript is a strongly typed language over dynamically typed javascript especially AS3.

So, ActionScript is used to code interactive objects in the games for my research project.

(iii) PHP

PHP is an open source server side programming language available free of charge and can be obtained easily from the Web. Its associative required software like MySQL, Text Editors and Apache Server are also freely available. Its coding style is quite easy to understand and it is very efficient on multi-platforms like Windows, Linux, and UNIX, etc. It is very flexible but powerful language, most suitable for developing dynamic web pages. Nowadays the use of PHP is popular among programmers.

PHP is executed exclusively by server and therefore needs nothing from end users. It is not much dependent upon external plug-ins to run the programs. PHP has also upper hand in running multimedia files.

Data handing has also been pretty handy in PHP in which the programmers can easily store data into excellent database management system such as MySQL.

Hence, in this research project, PHP is used to transfer data from the game to database such as score, player's information, time access, etc.

(iv) phpMyAdmin- MySQL Client: Database Administration Tools

There are many MySQL Clients (or database administration tools) such as MySQL Front End, Tora, mysql, phpMyAdmin etc. phpMyAdmin is a PHP based GUI administration tool for MySQL. That means phpMyAdmin is a PHP script meant for giving users the ability to interact with their MySQL databases. It is web-based or online Database Administration. It runs on any server capable of handling PHP. For this research, the database management of the game will be handled by phpMyAdmin. The game stores all of its information in the MySQL database. Data stored in the MySQL database is accessible through phpMyAdmin.

(v) Adobe Dreamweaver

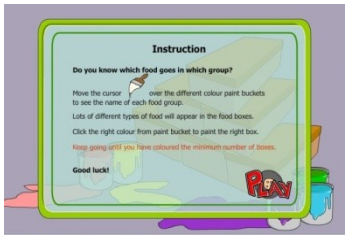
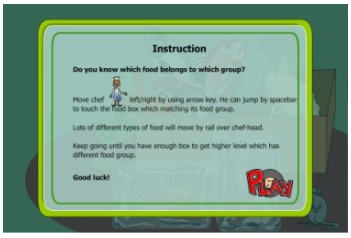
Adobe Dreamweaver is a web design and editing tool that has facilitated simpler coding for web site for designers. Great feature in Dreamweaver is the layout tool. It can be used to get an idea of where to put navigation, menus, pictures, etc. Dreamweaver is compatible with Windows operating systems. It supports technologies like JavaScript, ActionScript and other scripting frameworks and languages including PHP. This research use Dreamweaver for outlining the layout of webpage game.

6.2.2 Method

6.2.2.1 Game Design

Both games were built on the same content of the topic – *food groups*. Table 6.2 shows how to implement FoodGroups-A and FoodGroups-B differently with regard to the eight heuristics.

Table 6.2 How to implement FoodGroups-A and FoodGroups-B differently with regard to the eight heuristics

Essential heuristics
DEG-7-11#1: Learning Goals
FoodGroups-A  Before starting game, an instructional page is provided. It lets children know the goal of the game. The goal is a simple, concise and clear sentence such as "Do you know which food belongs to which group?", "Do you know which food goes in which group?". There is no goal on scoring, unlike most purely entertainment games which state the performance goal in terms of high score, for DEGs just a learning goal is presented.
FoodGroups-B 

DEG-7-11#2: Multimodal Instructive Instructions

FoodGroups-A

Before playing the game, the instruction in form of a short video clip (24 seconds) is presented to explain how to play.

When playing the game, "Help"  button is provided where children can press when they want to get more detail about the game such as how to play, what the basic knowledge they should know in order to play game better, where to focus while playing the level, especially how to get correct answers.

The supported instruction is dropped down as a small window when pressing. The pages of instructions are in form of animation with short texts. Especially, there is a page of animation explains how to get correct answer (how to take the right food in the right group);

Screenshot 1: There are two food groups and four boxes of food as the example.

Screenshot 2: The food boxes will float up to match their own groups, it is showing the right answer of matching.

FoodGroups-B

Before playing the game

Screenshot 1

Screenshot 2

Recommendable heuristics
DEG-7-11#3: Different Genders
FoodGroups-A  The game can be played by both genders. Children can select their own favourite avatar.
FoodGroups-B  Only one avatar is provided. Adult male chef is selected by the game designer. Current TV programs show that adult males are chef in most of cooking programs.
DEG-7-11#4: Relaxation
FoodGroups-A   All three sub-games are relaxing to play because the ***minimalistic interfaces*** are applied.    *1st sub-game*: it has only one interactive control and one rule.   It is a multiple choices and matching game. Children just drag and drop a choice to get right answer. From the Pilot Study, a multiple choices game gave the children a better sense of control over the other games.   In order to encourage children to learn basic knowledge, initial sub-game contains no score, and there is no penalty or even reward while playing. However, other kinds of feedback are provided to let them know their decision, such as sound effects.    *2nd sub-game*: It has only one interactive control and one rule.   Children move the mouse to move the paintbrush icon, then click the paint bucket icon to get a colour, then click the box area to paint correct colour of each food group.   Children just try to get the minimum number of food box. Otherwise, the children cannot go to next level.

3rd sub-game: it has only two interactive controls and two rules.

Mr.Chef can move left-right by arrow keys, jump to collect a food box and avoid a mouse by spacebar.

Children lose 10 points if Mr.Chef touches a food box which doesn't match the food group.

Children lose 1 “chef life” if a mouse touches Mr.Chef.

Children should not let the score drop to 0 or run out of chef lives.

Having appropriate speed:

1st sub-game: it has no moving object, so children do not need to race with speed.

2nd sub-game: it has no moving object, so children do not need to race with speed.

3rd sub-game: it has two moving objects; moving food boxes and running mice.

A new food box is generated randomly every 2 seconds and moves across the screen by a constant speed (a value of 5 pixels, 12 times per second). A new box will be generated quicker every 1.5 and 1.3 seconds respectively in next two levels. Also, the moving speed will be faster with a value of 7 and 8 pixels in next two levels in order to make the levels more challenging.

A mouse is generated every 10 seconds and moves across the screen by a random speed. All three levels have the same speed of generating and moving.

Both objects’ speed was adjusted appropriately to requirement of the 4 representative children after the pilot-test. Children can have potential to race with the speed.

Having no time pressure: The sense of time may be a factor to increase pressure while playing. The game does not make children feel tense. They can play or stop playing for a while whenever they want. Children do not need to complete the game within a time limit.

1st sub-game: The game does not force them to play within a time constraint; they can pass the sub-game as long as they get the right answer of each question about food groups.

2nd sub-game: It has no time constraint. They can pass the levels and complete the sub-game as long as they get the minimum right food boxes.

3rd sub-game: As long as they get the higher score, they can pass the level.

FoodGroups-B

The game is not relaxing to play;

It has two interactive controls and two rules.

Mr.Chef can move left-right by arrow keys, jump to collect a food box and avoid a mouse by spacebar.

Children lose points if Mr.Chef touches a food box doesn't match the food group.

Children lose 1 “chef life” if a mouse touches Mr.Chef.

Children should not let to run out of chef lives or to have too much wrong boxes.

But there is no interface for scoring. They cannot know their progressive score. This point might make children feel bored because they do not know when they will pass the level.

Having inappropriate speed:

It has two moving objects; moving food boxes and running mice.

A new food box is generated randomly every 2 seconds and moves across the screen by a constant speed (a value of 5 pixels, 12 times per second). A new box will be generated quicker every 1.9, 1.7, 1.5 and 1.3 seconds respectively in next higher four sub-levels. Also, the moving speed will be faster with a value of 6, 7, 8 and 9 pixels in next two levels in order to make the levels more challenging.

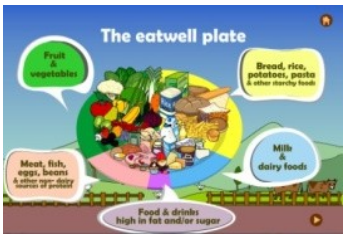
A mouse is generated every 8 seconds and moves across the screen by a random speed. However, the speed of objects (moving food boxes, mice) are faster than FoodGroups-A. Also, the enemies (mice) run in faster and more frequent.

DEG-7-11#5: Multi-levels

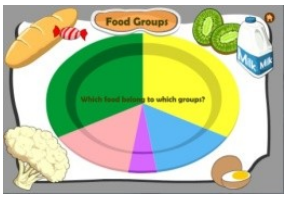
FoodGroups-A

The game is separated into 3 sub-games. Various tasks of distinguishing food groups are provided in sub-games and their own levels. The tasks are provided at a pace, in a proper ease and speed of the practice.

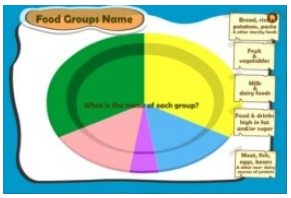
1st sub-game: It presents basic knowledge of food groups.



Children are given 30 seconds (or they can click next whenever they want before running out of time) to remember the Eatwell Plate (the plate represents 5 food groups which UK primary school students have to learn according to UK curriculum) such as: How many colours are there in the plate? Which food group does each colour represent? and How big should each section of the plate (food group) be?



Then, they have to answer basic questions about the food groups. The questions are multiple choices and matching.



This sub-game introduces basic knowledge on food groups to children.

2nd sub-game: It associates with previously learned and related ideas.

Children apply the food groups colours from 1st sub-game to paint a food box to match its group.

There are 3 levels. Many examples of foods in the levels enable children to practise distinguishing the food groups.

3rd sub-game: It encourages children to apply previous knowledge to distinguish the food groups on their own.

Children apply the food groups colour from 1st and 2nd sub-game to collect food boxes that match to their respective groups.

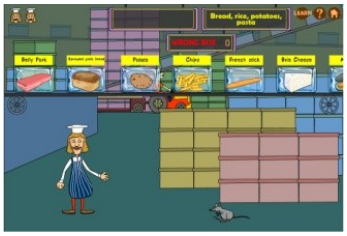
This sub-game is separated into 3 levels. Some examples of foods look similar and might lead to misclassifications in wrong groups. Children have to apply the previous practice of previous sub-games. For example, butter looks like product of milk, but it is not in Milk group.

1.) Coloured boxes and lids can hint children to find foods they need.

2.) Only coloured lids (all boxes are of the same colour) can hint children to find foods they need.

3.) No more colour hints

FoodGroups-B



There are no initial sub-games or levels to serve as disguised tutorials.

The game does not provide different levels of challenge for different skill levels of different children.

The game does not provide new challenges at all.

DEG-7-11#6: Incorporate Reminders

FoodGroups-A

Every sub-game uses colours as hints to remind children of the food groups. 5 colours are related to 5 food groups.

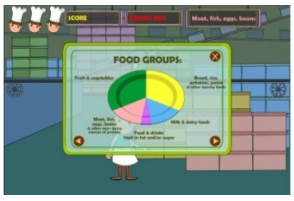
1st sub-game: Children are presented the different colours of 5 food groups

2nd sub-game: The game provides 5 coloured paint buckets associated with the names of 5 food groups.

Children have to pick the right colour from a paint bucket and paint the right food boxes.

3rd sub-game: The first level of this sub-game provides colours as hints on the food boxes, the second level provides the coloured lids as hints, and the third level does not provide any colours or any hints on the boxes. The hints are gradually removed with the levels

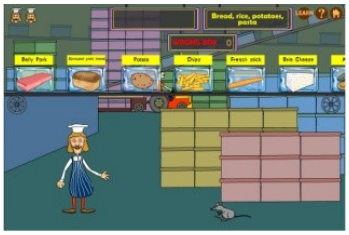
"Help"  button of each sub-game also are prepared as small windows to display the Eatwell Plate. It informs the concluded knowledge of food groups such as food groups colour, food groups name, portion of each groups. Children can recall memory about food groups while playing each level.



FoodGroups-B

The game does not use any reminder or hint.

Children have to look at the name of the food group and use trial and error method to learn which food belong to which group by themselves.



DEG-7-11#7: Cartoon-like Animations

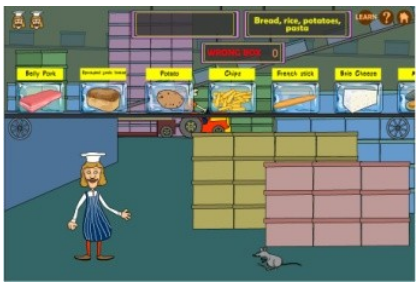
FoodGroups-A

The game story takes place in a food packaging factory, food boxes are sent by moving belts to the transportation section in order to distribute to many restaurants. The cartoon-like animations background of the game shows the belts of moving products. A truck is ready to run out to deliver food boxes to restaurants, the engine is starting, there is some smoke blowing out from its pipe. The animation background let children imagine the atmosphere of a real food factory.

Characters in the game are designed by using cartoon-like animations such as the female/male chef can swing their hands and legs to run, the mice also can swing their legs when running.

The animated cartoons can enhance the attractiveness and fun of the game, though they may not be essential for learning.

FoodGroups-B



The story of FoodGroups-B is same as FoodGroups-A, it also takes place in a food packaging factory and does the same processing. But, the background and characters of FoodGroups-B are not designed by using cartoon-like animations. They are designed by using static cartoon-like, except the main moving belt of products for gameplay.

At the background of the game, the product belts are not moving; the truck look like stopping, the engine is not starting, the static graphic of smoke is not blowing out from its pipe.

Characters in the game are designed by using static cartoon-like such as the chef cannot swing their hands and legs to run; the mice also cannot swing their legs when running.

DEG-7-11#8: Rewards and Punishments Feedback
FoodGroups-A Children are given the informative feedback such as reward scores and punishment scores. The feedback is provided to inform children whether the answers are correct or not. They can use trial and error method to find the correct answer. Also they can know their progress      Audio messages such as “Well Done”, “Great”, “Excellent”, etc. are also delivered to let children know that they can have correct answer.
FoodGroups-B No in-game feedback interfaces such as reward / punishment scores or audio message are provided to inform children about their progress. Just plain text, such as “Well Done” and “Try Again” are used to let children know their decision.   

6.2.2.2 Game Structure

(i) FoodGroups-A

The game prototype was developed by me with the aim to educate children on the knowledge of food groups. It composes of most preferable features and was informed by all 8 heuristics of DEG-7-11 v1. It comprises three major components: three sub-games, two game tests, and two questionnaires (pre-gameplay and post-gameplay). It was 2-dimension graphic design (Figure 6.1). Each sub-game is separated into different number of levels. Figure 6.2 depicts the structure of the game.

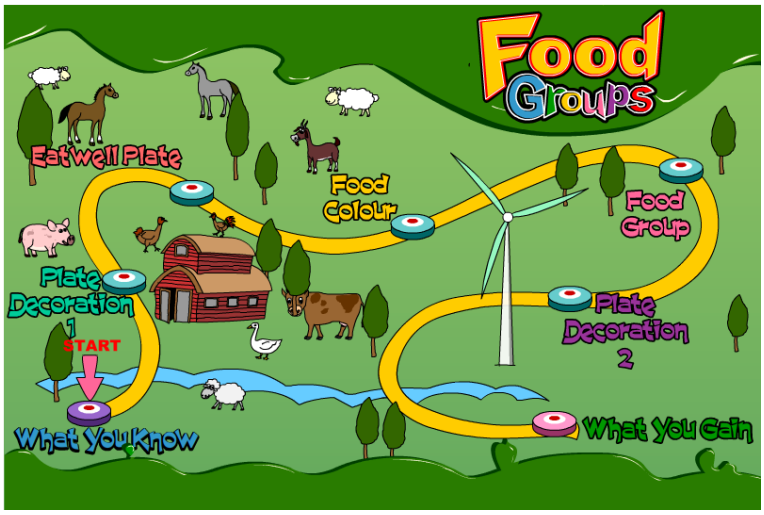


Figure 6.1 Implemented FoodGroups-A

(http://www.cs.le.ac.uk/people/kk207/FoodGroupsGame/index.html)

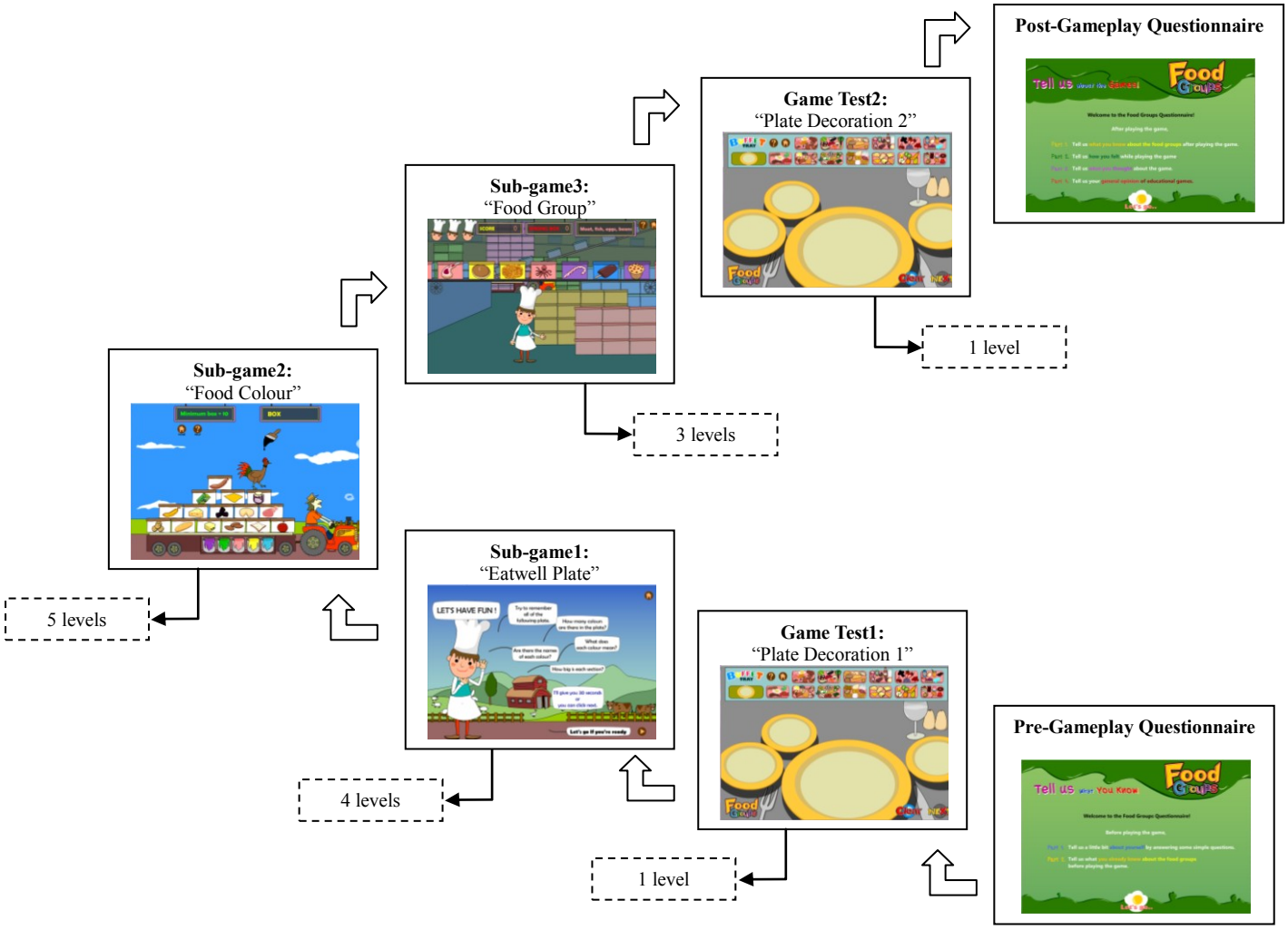


Figure 6.2 The structure of FoodGroups-A before the pilot test

(ii) FoodGroups-B

FoodGroups-B composes of less preferable features and was informed by the two essential heuristics. It comprises three major components: one game, two game tests and two questionnaires (pre-gameplay and post-gameplay). The game also educates children on the knowledge of food groups. The game prototype was a 2D game. The graphic design of FoodGroups-B is shown as Figure 6.3 and its structure in Figure 6.4.

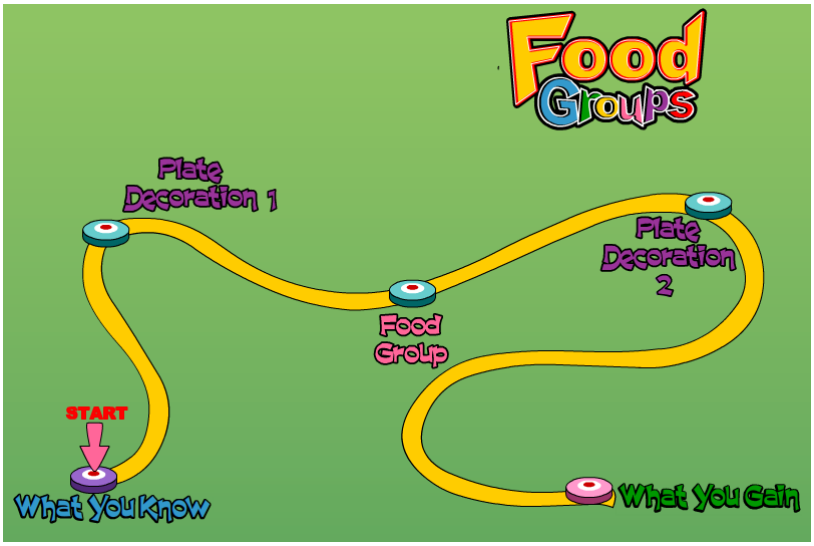


Figure 6.3 Implemented FoodGroups-B

(http://www.cs.le.ac.uk/people/kk207/AlternativeFoodGroupsGame/index.html)

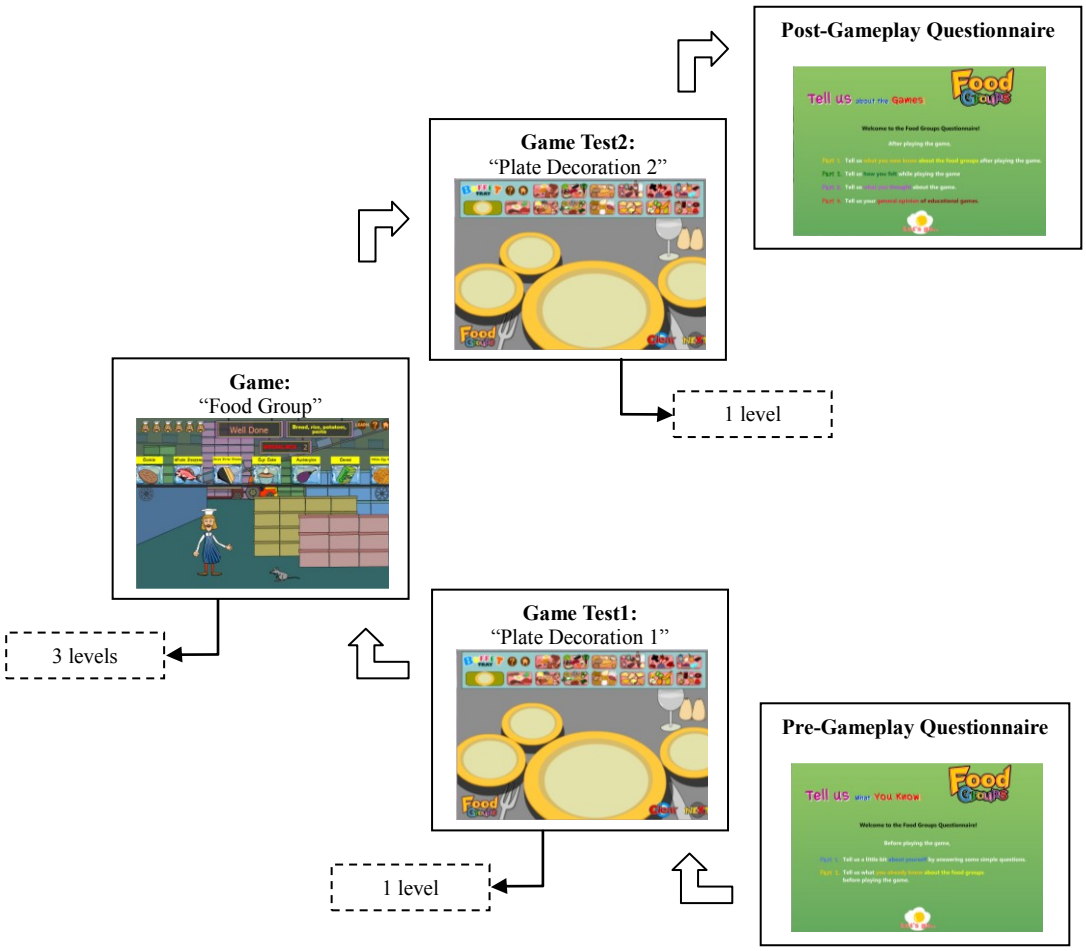


Figure 6.4 The structure of FoodGroups-B before the pilot test

(iii) Questionnaires

The measurement instrument for evaluating and validating the games is online-questionnaire. It consists of two questionnaires: the Pre-Gameplay Questionnaire and the Post-Gameplay Questionnaire. They have different items, which are grouped as parts, as depicted in Figure 6.5. The same sets of questionnaires are used for FoodGroups-A and FoodGroups-B.

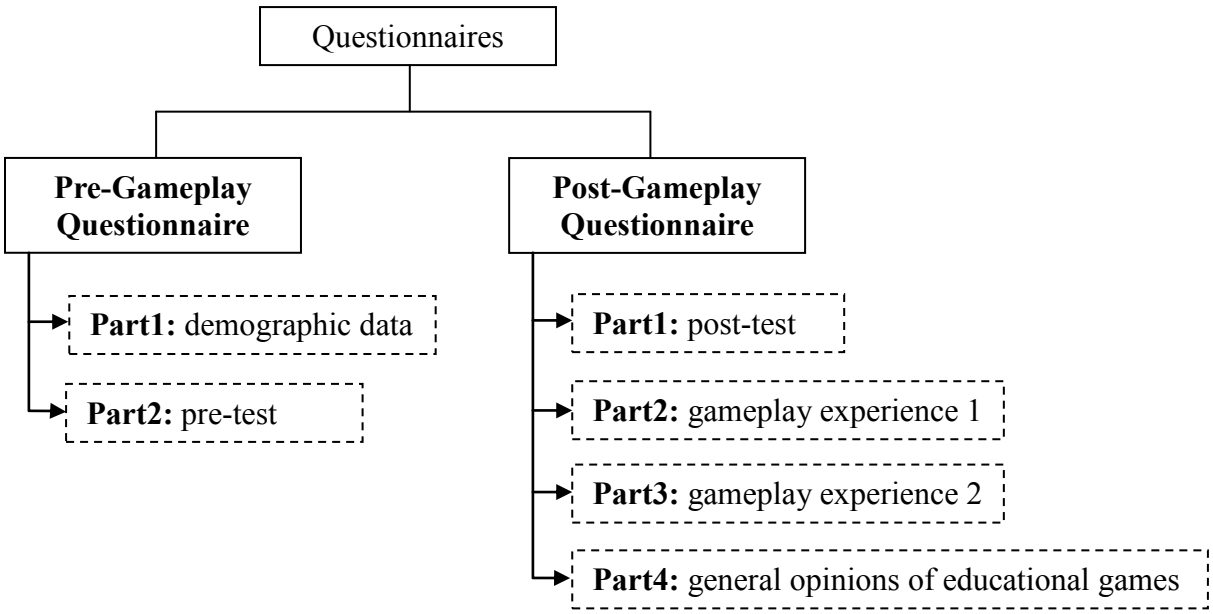


Figure 6.5 The structure of questionnaires before the pilot test

Before playing the games, a set of demographic data of each children were collected, and then a set of pre-test questions were displayed to test children' s basic knowledge on food groups; there were 7 questions. It took the children approximately 5 minute to complete it.

After playing the games, the same set of test questions were shown again in order to test children' s gained learning. Then, gameplay experience was studied by using the Kids Game Experience Questionnaire (KidsGEQ) proposed by Poels and her colleagues (2008). Children were asked to indicate how they felt while playing the games. They rated each of the items using the following scale: Not (0), Very little (1), A bit (2), Fairly (3), A lot (4).

After that, a set of 16 statements of gameplay experience derived from the GameFlow model would be presented. The criteria of the GameFlow model of Sweetser and Wyeth (2005) were translated into the set of statements understandable for children, compiled as Part 3 of the questionnaire and used to evaluate what the children thought about the games. Based on their experience with the game, the children rated each of the statements using a five-point scale (1: Awful, 2: Poor, 3: Neutral, 4: Good, 5: Brilliant). Not only the close-end questions but also open-ended questions were used in the questionnaires. Text boxes were used to collect game problems the children had while playing the games. The children were asked to describe their likes, dislikes and

suggestions for games improvement in the given text boxes.

6.2.2.3 The Pilot Test

After the games were developed, the Pilot Test was exploratory, focusing on identifying as well as understanding the interaction problems experienced by primary school children when playing the games. Children were briefed about the purpose of the test and provided support if needed.

The goal of the Pilot Test was geared towards testing the feasibility of the games and questionnaires with primary school children. It investigated how the games would be played smoothly as well as how the questionnaires would be administered with primary school children. Questions like "How long should a game for primary school children be?", "Are there any bugs in the games?", and "Are there any features that school children strongly dislike?" were considered. Also, questions like "How long should a questionnaire for primary school children be?", and "Which wordings/statements are hard to understand by primary school children aged 7-11?" were addressed.

Four children - 2 boys and 2 girls - were recruited through my personal contacts. All participations were voluntary. I went to the children's places (e.g. home, their parents' office) with which they were familiar. Each child was asked to play the game on an individual basis. One boy and two girls with an average age of 9 years old tested FoodGroups-A. One boy aged 9 years old tested FoodGroups-B. The testing was under my close observations. Interviews were conducted right after they had finished playing the game. A testing session took approximately 90 minutes.

While the child was playing the game, I was taking notes based on an observation coding scheme (Table A.2). The observations focused on how children interacted with the games, the coding scheme was used to count as complementary data. The screen capture was recorded under the permission of their parents; I could replay the child's activities after that. Besides, a semi-structured interview was conducted, allowing me to ask for explanations for the observed usability problems of the games and for the issues with the questionnaires such as ambiguous wordings. Specifically, the preference and further comments on the games were captured according to the interview protocol (Appendix B). With the empirical data collected, the games were improved accordingly.

6.2.3 Results and Discussions

6.2.3.1 Game Structure after the Pilot Test

The Pilot Test investigated the feasibility of using the games and questionnaires with primary school children in particular. Problems of using the games and questionnaires were explored.

(i) FoodGroups-A

Based on the children's feedback and on further insights into contextual constraints for empirical studies, it enabled me to redesign some features of FoodGroups-A, thereby improving the game usability and gameplay experience.

As a whole session of an empirical study was set to be around 90 minutes, it did not meet a school's condition. The time limit of 50 minutes would be imposed by a school's timetable; the length of the game had to be shortened. Some levels of some sub-games should be eliminated. Also the length of some levels should be shorter.

The number of levels of Sub-game2: "Food Colour" was reduced from 5 to 3. Also the level length of Sub-game3: "Food Group" was shortened by reducing the number of "chef lives" in the game. Figure 6.6 depicts the structure of FoodGroups-A after the pilot test.

Moreover, some features which were strongly disliked, such as the annoying running mice, were modified. The speed of the running mice was adjusted to be slower. Some errors and bugs in the game were found and removed.

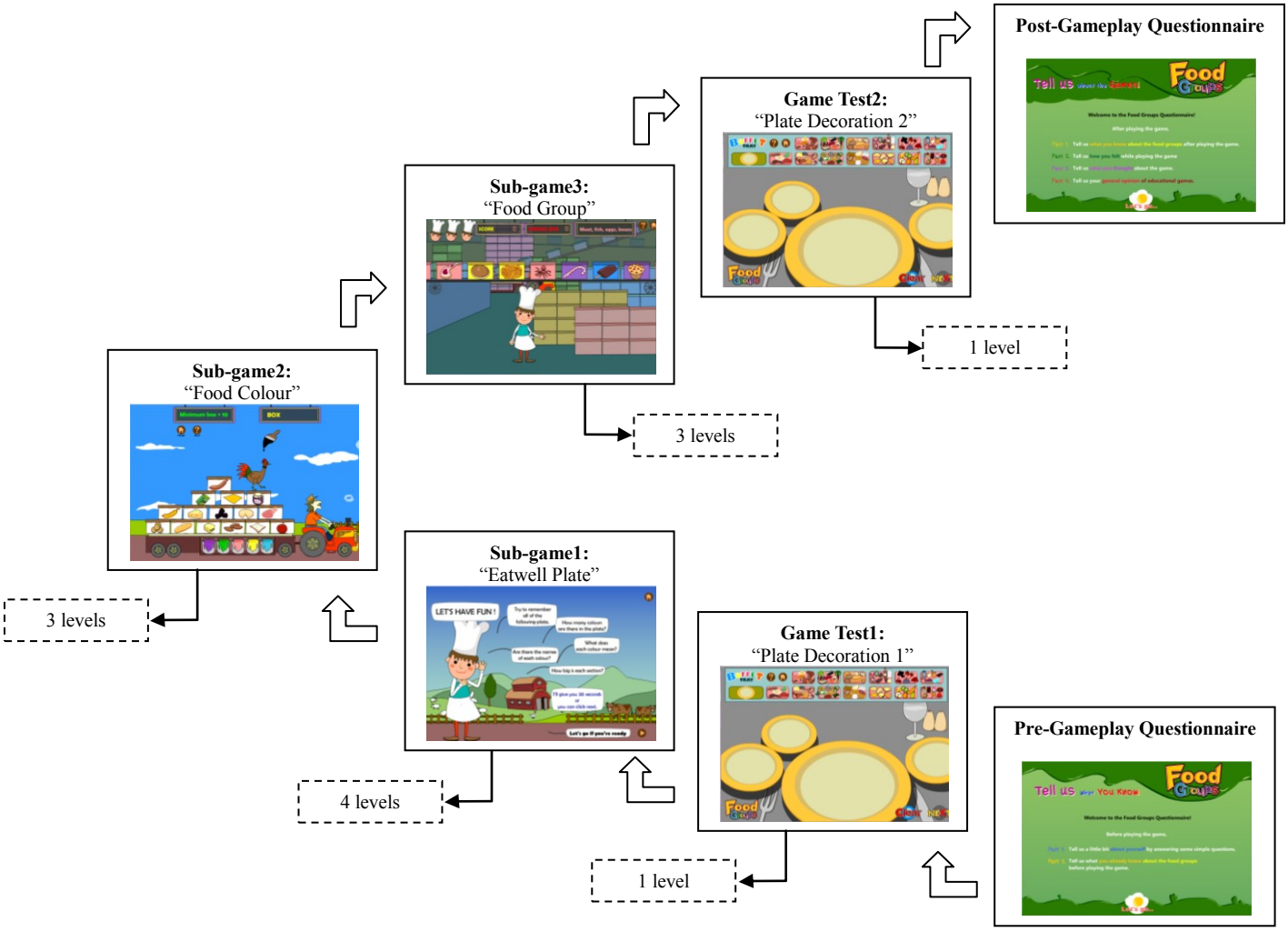


Figure 6.6 The structure of FoodGroups-A after the pilot test

(ii) FoodGroups-B

Same as FoodGroups-A, based on the time limit imposed by the schools, the length of some levels was shortened. The level length of Game: "Food Group" was shorter. Figure 6.7 depicts the structure of FoodGroups-B after the pilot test. Some features which were strongly disliked were refined, such as the speed of the sliding food boxes was slower. The number of "chef-lives" was increased so that the children could play longer before the game over when all the chef-lives were lost.

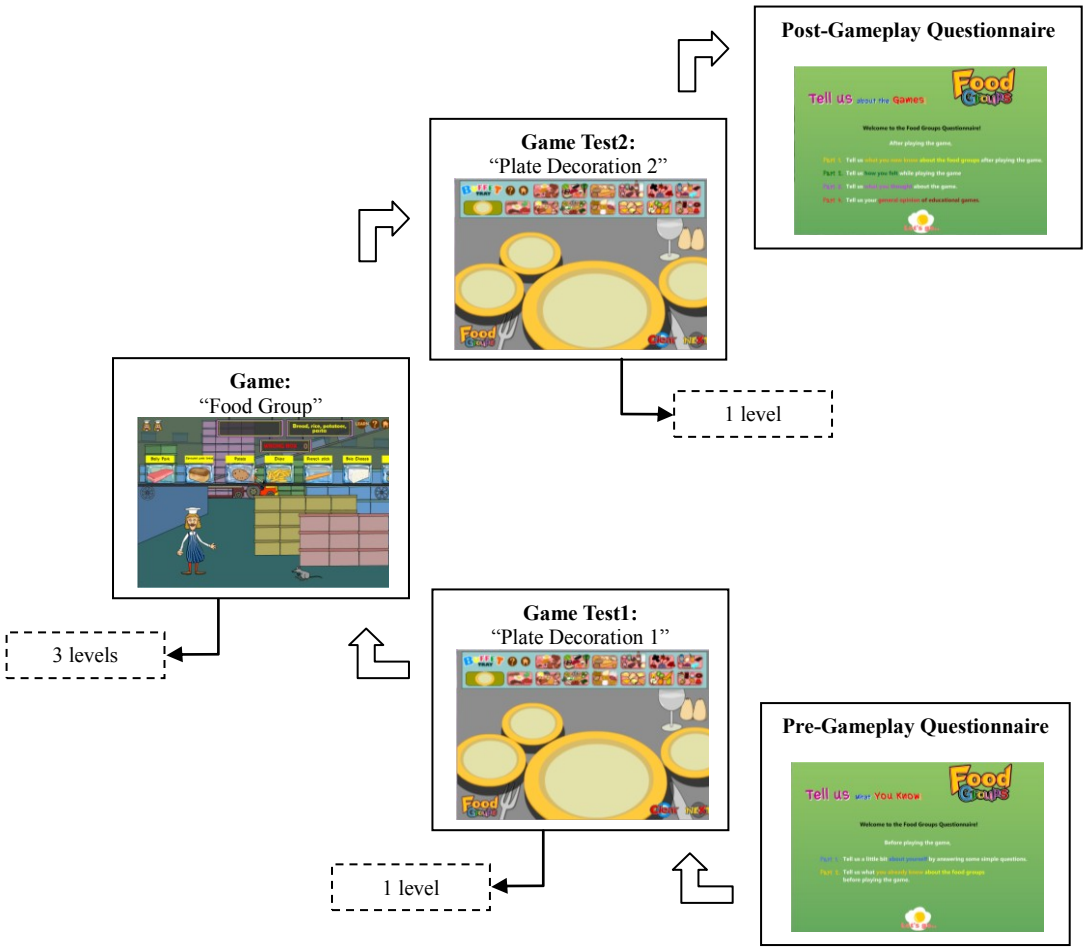


Figure 6.7 The structure of FoodGroups-B after the pilot test

(iii) Questionnaires

The question of "How long should a questionnaire for primary school students be?" was answered. There were still two types of questionnaire: the Pre-Gameplay Questionnaire and the Post-Gameplay Questionnaire. However, to mitigate the potential problem of mental fatigue, some parts of each questionnaire were adjusted. The part of "*general opinions of educational games*" which originally belonged to Post-Gameplay Questionnaire was moved to Pre-Gameplay Questionnaire in order to balance the time for completing all questionnaires within the time limit (Figure 6.8).

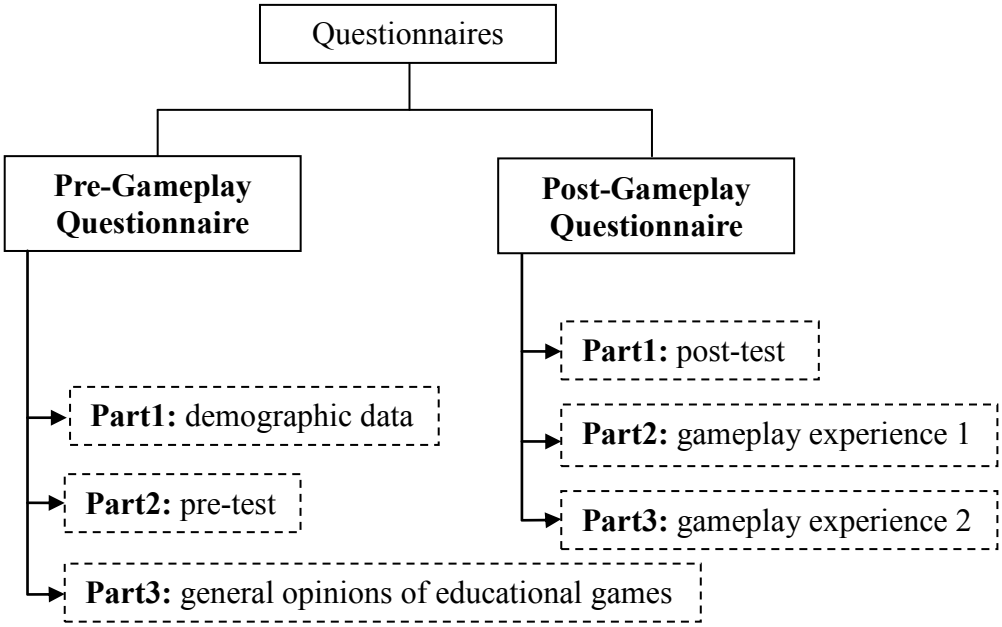


Figure 6.8 The structure of questionnaires after the pilot test

To respond to the question of how understandable/confusing statements in the questionnaire, the test result revealed which wordings/statements were hard to understand by primary school children aged 7-11. Some wordings were slightly altered, such as "picture" instead of "graphic"; "exhausting" instead of "tiresome". Although some wordings or sentences were changed, the main idea of the statement still was the same.

In addition, the scale indicating gameplay experience or how kids felt while playing the games of KidsGEQ were modified from this scale: Not (0), Very little (1), A bit (2), Fairly (3), A lot (4) to the following scale: Not at all (0), Very little/Slightly (1), Moderately/Quite (2), Fairly (3), Extremely/Very much (4).

6.3 Discussions

The result from the study was the two new DEGs. The study applied Gestalt theory to the interaction design (e.g. Dooley & Tuovinen, 2002). It could support that integrating of the preferable features in a game is better than separating of the individual feature in each game. However, having a set of preferable features is not enough to

create an enjoyment and educational effective game. A DEG design guideline is also needed. It could argue that DEG-7-11 v1 could be applied as design guideline for designing a DEG especially for children aged 7-11.

6.4 Conclusion & Outlook

Having the two DEGs is the main contribution from this chapter. The two DEG prototypes have specific characteristics created by integrating the preferable features extracted from the selected games for the Pilot Study as well as applying the heuristics of DEG-7-11 v1 for designing. They would be assessed with children on a group basis. The URLs of the games are as follows.

FoodGroups-A:

http://www.cs.le.ac.uk/people/kk207/FoodGroupsGame/index.html

FoodGroups-B:

http://www.cs.le.ac.uk/people/kk207/AlternativeFoodGroupsGame/index.html

Chapter 7: Main Study: Validation of DEG-7-11 v1

The findings of Main Study where the first version of DEG-7-11 heuristics were validated with primary school children are reported in this chapter. The final versions of the two FoodGroups games were evaluated. Systematic evaluations of the two new games with the target group allow me to confirm the assumed key benefit of DEG-7-11 v1 of enabling designers to create DEGs for children to learn a topic effectively and with fun.

Apart from the validation study by evaluating two game prototypes, I developed an alternative validation approach where children's agreements on the child-friendly statements derived from the DEG-7-11 v1 heuristics were evaluated by children aged 7-11. While such evaluation data alone are not sufficient for making a solid conclusion about the effectiveness of DEG-7-11 v1, they can serve as additional evidence. Both validation methods are described in the following.

7.1 Background

DEG-7-11 v1 is a set of the eight heuristics for designing DEGs for children aged 7-11 years old (Chapter 5). It is assumed that if a game is designed by following the heuristics, the game will enable children to have better learning outcomes and experiences. To further substantiate the empirical base, a validation study was conducted with 182 children aged 7-11 years sampled from different schools without involving any of the children in the Pilot Study (Chapter 4).

I also provided additional evidence of evaluation data to make the conclusion about the effectiveness of DEG-7-11 v1 more solid. The DEG-7-11 v1 heuristics were converted into child-friendly statements and rated by children to find their agreements.

7.2 Research study

This study aims to empirically evaluate the set of DEG-7-11 v1 heuristics by comparing the experiential and educational values of the two new DEGs, which have been developed by fully following and partially following DEG-7-11 v1, respectively. Moreover, a set of child-friendly statements converted from DEG-7-11 v1 would be rated by children.

7.2.1 Procedure

This validation study is reported in the chronological order of the activities conducted in the Main Study. The activities in the validation study were in this order: 1) the purpose and procedure of the study were described to the children; 2) children were then asked to provide their demographic data; 3) next, they were asked to fill out the pre-gameplay questionnaire consisting of eight statements, it is the validation of DEG-7-11 v1 by children rating; 4) they were randomly assigned to two groups and played either FoodGroups-A or FoodGroups-B individually under my observation; 5) before playing the game, children completed the Pre-Test, then completing the Post-Test after they finished playing, it was used to validate the educational value of the games 6) they were asked to fill out two post-gameplay questionnaires: gameplay experience measured by KidsGEQ and gameplay experience measured by the statements derived from the GameFlow model; and 7) they were interviewed (Figure 3.5). These steps and their results are presented in the following detail.

7.2.2 Participants

The validation study was conducted in 2013-2014 at eight public (or state) primary schools in UK - where the same curriculum is adopted. Altogether 182 children aged 7 to 11 years were involved in this study (M = 9.55; SD = .96). All participations were voluntary and consented by the children and their parents/carers and school authorities. A time limit of 50 minutes was imposed, because of the school timetables. Due to this time constraint, some children did not complete the post-test, especially the youngest age group (i.e. children aged 7 years).

In the beginning of a validation study, I first described the purpose and procedure of the study to the children. The general information about DEGs was explained such as purposes and features of them, example names of DEGs that children might be familiar were mentioned in order to encourage them to aware of the difference between entertainment games and DEGs.

Children then asked to provide their demographic data: age, gender, and game experience (Table 7.1). There were two close-end questions with four options on game experience: *how many hours per day*; *how many days per week*. A child was classified as having low game experience if her answers are: (‘never’ or ‘2 hours or less’) *and* (‘never’

or ‘2 days or less per week’). The other answer combinations were classified as having high game experience if her answers are: (‘3-5 hours’ or ‘over 5 hours’) *or* (‘3-5 days’ or ‘Everyday’).

Table 7.1 The demographic data of the children

Age (years)	7	8	9	10	11	Total
Original number of children	12	14	29	116	11	182
Girl: Boy ratio	8:4	6:8	21:8	67:49	2:9	104:78
Low: High game experience	7:5	4:10	12:17	46:70	2:9	71:111

7.2.3 Method 1: Validation of DEG-7-11 v1 by Evaluating Two Game Prototypes

The two game prototypes for teaching children about food groups by fully and partially following DEG-7-11 v1 were developed (Chapter 6). An empirical study was conducted to compare educational value and the gameplay experience of the two games. Results of the study could reveal how specific game features as informed by DEG-7-11 v1 would benefit the children. In addition, it was hypothesized that FoodGroups-A could induce in the children better learning outcome and more positive gameplay experience than FoodGroups-B.

7.2.4 Method 1A: Validation of the educational value of the games

Children were randomly assigned to two groups and tested either FoodGroups-A (n = 94) or FoodGroups-B (n = 88) individually. Prior to playing the game, the children were asked to complete the *domain-specific knowledge Pre-Test* on food groups and to make their own meal through a small game named “Make a Meal”. After playing the game, the system redirected automatically to the *Post-Test* (the same as the Pre-Test) and to “Make a Meal” again, followed by the *two gameplay experience questionnaire*s.

The Pre-Test, Post-Test, and “Make a Meal” were designed to compare the educational value of the games. The aim was to identify how specific features informed by the DEG-7-11 v1 heuristics as opposed to not using them would benefit young players.

This study was aimed to verify a null hypothesis (H):

H1: There are no significant differences in knowledge on food groups between two groups of children aged 7-11 years who played one of the two games independently.

7.2.5 Apparatus

7.2.5.1 Pre-Test and Post-Test

The knowledge tests which consist of Pre-Test and Post-Test were constructed and integrated into the two games. The set of questions was derived from the content of FoodGroups-A and FoodGroups-B game. Both tests had the same set of 7 close-ended questions in order to compare the knowledge gain of children before and after playing the game. It took the children ca. 5 minutes to complete it. Figure 7.1 shows an example.

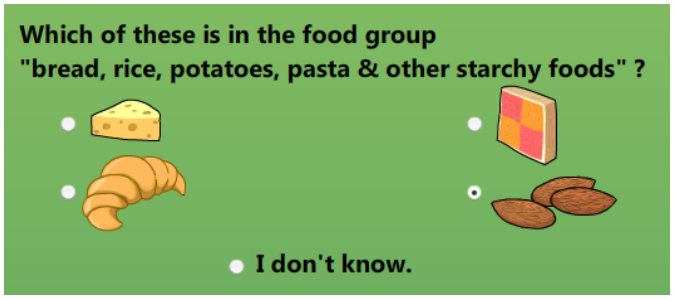


Figure 7.1 A sample item in the pre/post-test knowledge questionnaire

7.2.5.2 "Make a Meal"

Furthermore, "Make a Meal" is another test, the appearance of the test looks like a game (Figure 7.2). Before playing the game, children were asked to create their own meal. After they have dragged various foods to put on the dishes, they are given some feedback in their choices of foods. The feedback informs them roughly about the different types of foods they have picked. However, in this stage they will not know which type of food belongs to which food group. Then, after playing the game, they were asked to create a meal again. They need to apply their knowledge on food groups that they just have learnt from playing game to make a healthy meal. After they have balanced their meal, they are given a report page on their choices of food groups. The report informs them entirely about the different food groups they have chosen, the

comments on lacking of some food groups, such as “Oh! If we don’t get enough these foods we can end up feeling tired and find it hard to concentrate.”, as well as the recommendations on how to make a better balance plate such as “Oh! We should try and eat 5 portions per day – yes five!”.

The rationale was to compare if the two meals were notably different with the latter being better than the former in terms of food groups inclusion and balance. Especially, the report page given after balancing a meal could remind them to apply the knowledge they just have learnt.

Figure 7.2 “Make a Meal” test

7.2.6 Results and Discussions

The main goal of this study is to find out whether and to what extent the game which was designed by following all the eight DEG-7-11 v1 heuristics could contribute to the learning of food groups by children aged 7-11 years. A between-subjects design was employed with the game design being the independent variable. One set of children (n = 59) played FoodGroups-A serving as the experimental group whereas the other set played FoodGroups-B (n = 67) serving as the control group. The two DEGs were compared in terms of their educational values. A within-subject design was also employed to measure the gaining knowledge scores before and after the individual children played the game in respective groups.

To evaluate H1, the knowledge test scores, Pre-Test and Post-Test, as well as the

number of food groups chosen to create a meal in "Make a Meal" over all the children in the respective group were compared.

7.2.6.1 Knowledge test score of Pre-Test and Post-Test

(i) Between-group comparisons

The children's knowledge test score, Pre-Test and Post-Test, were calculated. First, the sum of Pre-Test and the sum of Post-Test were computed over all the children in the respective group. Then, the Difference Score of Post-Test and Pre-Test were calculated over all the children in the respective group. After that, the difference in the Difference Score between the two groups was compared (Table 7.2).

As all the *p* values of the Shapiro-Wilk tests were smaller than 0.05, indicating the data were not normally distributed, non-parametric Mann-Whitney tests were then used to evaluate H1.

Table 7.2 Comparing the Difference Score between two groups

GAME / Test score	FoodGroups-A			FoodGroups-B			Statistics	
	Mean	N	Std.	Mean	N	Std.	U	*P*
Difference Score of Post-test & Pre-Test	1.44	59	1.67	.54	67	1.22	-4.057	.000**

Table 7.3 Comparing the Difference Score between genders of each group

GAME	FoodGroups-A								FoodGroups-B							
	Girl			Boy			Statistics		girl			boy			Statistics	
Test score	Mean	N	Std.	Mean	N	Std.	U	*p*	Mean	N	Std.	Mean	N	Std.	U	*p*
Difference Score of Post-test & Pre-Test	1.53	32	1.45	1.33	27	1.92	-.180	.857	.70	40	1.22	.30	27	1.20	-1.420	.155

The results, as shown in Table 7.2, indicate that the means for the Difference Score of Post-test & Pre-Test of the children who played FoodGroups-A were higher than those of FoodGroups-B. There was *significant difference* in learning gain (the

Difference Score) about food groups between the two groups of children who played two different games (U = -4.06, $p < .05$). Girls and boys who played their own assigned game gained the knowledge on food groups not different. There was no significant difference in the Difference Score of Post-test & Pre-Test between girls and boys who played the game in their respective group (Table 7.3).

(ii) Within-individual comparisons

Moreover, I wished to investigate any change in the knowledge tests scores before and after the individual children played the game. As the data were not normally distributed, non-parametric Wilcoxon Signed Ranks Test was used (Table 7.4). It is used to compare two sets of scores, Pre-Test and Post-Test, that come from the individual children. Then, non-parametric Wilcoxon Signed Ranks Test was used to compare the differences of each knowledge test score of individual children in each gender who played the game in respective group (Table 7.5).

Table 7.4 Comparing the knowledge test scores of the individual children before and after playing game

Knowledge Test / **GAME**	**Pre-Test**			**Post-test**			**Statistics**	
	Mean	**N**	**Std.**	**Mean**	**N**	**Std.**	**W**	***P***
FoodGroups-A	3.59	59	1.68	5.03	59	1.66	-5.291	.000**
FoodGroups-B	4.03	67	1.40	4.57	67	1.42	-3.304	.001**

Table 7.5 Comparing the knowledge test scores of the individual children before and after playing game and their gender by the two groups

Knowledge Test / **GAME**		**Pre-Test**			**Post-test**			**Statistics**	
		Mean	**N**	**Std.**	**Mean**	**N**	**Std.**	**W**	***P***
FoodGroups-A	**girl**	3.75	32	1.43	5.28	32	1.22	-4.098	.000**
	boy	3.41	27	1.94	4.74	27	2.04	-3.396	.001**
FoodGroups-B	**girl**	4.05	40	1.41	4.75	40	1.49	-3.195	.001**
	boy	4.00	27	1.41	4.30	27	1.26	-1.153	.249

The result shows that there was significant difference in learning gain on food groups of individual children before and after playing each game. Results show that both FoodGroups-A and FoodGroups-B can enhance specific knowledge on food groups of the participating children after they played. It can be inferred that since FoodGroups-B also designed by following DEG-7-11#1 and #2; which are essential heuristics; it shows that the essential heuristics can support learning although FoodGroups-B had a lower preference rating.

Furthermore, after playing FoodGroups-A, individual girls and boys gained more knowledge test scores importantly as there was significant difference in the knowledge test score before and after playing the game. The result was same as the individual girls who played FoodGroups-B. Contrast with the individual boys who played FoodGroups-B, although the Post-Test score was higher than Pre-Test score, their gaining knowledge was not changed importantly as there was no significant difference in the knowledge test score before and after playing the game (Table 7.5).

7.2.6.2 "Make a Meal"

(i) Between-group comparisons

The number of food groups chosen to create a meal in "Make a Meal" was counted and compared. First of all, the datasets were tested by the Shapiro-Wilk tests ($p < .05$), they were not normally distributed.

The Difference in the number of food groups chosen before and after playing game for each child who played the game in respective group was computed. Then, the difference of the meals between the two games was compared. Non-parametric Mann-Whitney test was used to evaluate the difference (Table 7.6). It can be assumed that children could make a balance meal after playing game.

Table 7.6 Comparing a meal between two groups

GAME / Test score	FoodGroups-A			FoodGroups-B			Statistics	
	Mean	**N**	**Std.**	**Mean**	**N**	**Std.**	**U**	***P***
Difference in the number of food groups chosen before and after playing game	.94	32	1.61	.86	43	1.66	-.275	.783

Table 7.7 Comparing a meal between genders of each group

GAME	FoodGroups-A								FoodGroups-B							
	Girl			Boy			Statistics		girl			boy			Statistics	
Test score	Mean	N	Std.	Mean	N	Std.	U	*p*	Mean	N	Std.	Mean	N	Std.	U	*p*
Difference in the number of food groups chosen before and after playing game	.75	20	1.71	1.25	12	1.42	-1.338	.181	.77	31	1.74	1.08	12	1.44	-1.099	.272

Although there was no significant difference in the number of food groups chosen before and after playing game between the two groups of children who played two different games (U = -.28, $p > .05$), the mean of difference in the number of food groups before and after playing the game was higher for FoodGroups-A than for FoodGroups-B. It implies that the children who played FoodGroups-A improved their knowledge on food groups; they could choose more various foods to create a balanced meal through playing FoodGroups-A more than through FoodGroups-B.

The result also shows that there was no significant difference in applying knowledge on food groups to make their own meal between genders before and after playing their game (U = -1.338, nA = 32, $p > .05$ and U = -1.099, nB = 43, $p > .05$). It can be explained that since "Make a Meal" is not a kind of testing specific knowledge; it is a small game used for observing how children apply their knowledge of food groups. When making a meal, children might look at only the appearance of the food images; it looks like a plate decoration. Hence, children did not care to balance their meal, but rather focus on decorating the plate. They just tried to choose various foods for decorating their meal without aiming to balance the food groups on the plate. Thus, "Make a Meal" might not suit for examining the children's application of knowledge.

(ii) Within-individual comparisons

Moreover, I wished to investigate any change in applying knowledge to make their own meal before and after the individual children played the game. As the data were not normally distributed, non-parametric Wilcoxon Signed Ranks Test was used (Table 7.8). Then, the test was used again to compare the meal of individual children in each gender who played the game in respective group (Table 7.9).

However, when comparing a meal of individual children, after playing FoodGroups-A, individual children could make their own meal better importantly as there was significant difference in the number of food groups chosen before and after playing the game (W = -3.067, $p < .05$). The result was same as the individual children who played FoodGroups-B (W = -3.059, $p < .05$) (Table 7.8).

Table 7.8 Comparing a meal of individual children before and after playing game

	Number of food groups chosen before playing game			**Number of food groups chosen after playing game**			**Statistics**	
	Mean	**N**	**Std.**	**Mean**	**N**	**Std.**	**W**	***P***
FoodGroups-A	3.47	32	1.67	4.41	32	.80	-3.067	.002**
FoodGroups-B	3.65	43	1.72	4.51	43	.77	-3.059	.002**

Table 7.9 Comparing the meal of individual children before and after playing game and their gender by the two groups

GAME		**Number of food groups chosen before playing game**			**Number of food groups chosen after playing game**			**Statistics**	
		Mean	**N**	**Std.**	**Mean**	**N**	**Std.**	**W**	***P***
FoodGroups-A	**girl**	3.70	20	1.45	4.45	20	.75	-1.917	.055
	boy	3.08	12	1.97	4.33	12	.88	-2.399	.016**
FoodGroups-B	**girl**	3.71	31	1.81	4.48	31	.72	-2.217	.027**
	boy	3.50	12	1.50	4.58	12	.90	-2.460	.014**

Furthermore, when comparing a meal of individual genders, after playing FoodGroups-B, both boys and girls could make their own meal better importantly as there was significant difference in the number of food groups chosen before and after playing the game (W = -2.217, $N_{girl} = 31$, $p < .05$ and W = -2.460, $N_{boy} = 12$, $p < .05$).

The result was same as the boys who played FoodGroups-A (W = -2.399, $p < .05$). Contrast with the individual girls who played FoodGroups-A, although they could make their own meal better after playing the game, their applying knowledge was not changed importantly as there was no significant difference in the number of food groups chosen before and after playing the game (W = -1.917, $p > .05$) (Table 7.9).

7.2.7 Summary

Overall, H1 is partially rejected because of the significance difference found in the learning gain through the knowledge-specific Pre- and Post-Tests and non-significant difference in the test "Make a Meal". It implies that FoodGroups-A, which was designed by following all the heuristics of DEG-7-11 v1 can enhance the development of the children's learning of this specific topic more than FoodGroups-B. However, FoodGroups-B, which was designed by following only two essential heuristics, can also support the learning, albeit to a lower extent than FoodGroups-A.

7.2.8 Method 1B: Evaluation of the gameplay experience of the games

Next, children were asked to complete two post-gameplay questionnaires which are *gameplay experience questionnaire*s. In this project study, two tools were used to measure gameplay experience. The first measure was the statements of KidsGEQ and the second measure was the child-friendly statements derived from the GameFlow model. The second measure emerged as DEG-7-11 v1 heuristics were derived from the GameFlow model, this could be a possible way to validate DEG-7-11 v1 heuristics. The details are described in Section 7.2.9 and Section 7.2.13.

Both measures were designed to compare the gameplay experience of the two games. Accordingly, I formulated a hypothesis that gameplay experience of the game designed by fully following the DEG-7-11 v1 heuristics would be perceived more favourably than the other game designed by partially following the heuristics.

I aimed to infer that if both measures provide same results, it convinces that the gameplay experience of the two games are reliable. Also, it can refer that the second measure, the child-friendly statements derived from the GameFlow model, was valid and can be used to evaluate gameplay experience. Also, it can imply that the DEG-7-11 v1 is validated.

7.2.9 Measure 1: Gameplay experience measured by KidsGEQ

Children were asked to complete the validated questionnaire KidsGEQ (Kids Game Experience Questionnaire) proposed by Poels and associations (2008).

This study was aimed to verify a null hypothesis (H):

H2a: There are no significant differences in gameplay experience as measured by KidsGEQ between two groups of children aged 7-11 years who played one of the two games independently.

7.2.10 Apparatus

UX in the context of playing games is called *game experience* (Bernhaupt, 2010). The purpose of evaluating game experience is to become aware of whether the game is fun to play and what kind of experience the player can obtain from playing the game.

It is unfeasible for me, who is not expert in HCI, to form comprehensive questions to measure how children feel or experience when playing digital games. In 2008, Poels and her colleagues (2008) proposed the Kids Game Experience Questionnaire (KidsGEQ) containing an all-embracing list of statements used for assessing in-game experiences in young children (8-12 years). It is a robust self report instrument that is able to fill out by children independently. It does not depend on types of game or platforms. It focuses on studying the effects of playing games, both positive (e.g. challenge, competence and flow) and negative (e.g. tension) ones. The KidsGEQ consists of 21 statements divided into 7 gameplay experience dimensions (see Table 7.10). The KidsGEQ is suitable completely for this research study which aimed to measure gameplay experience from children aged 7-11 years.

Table 7.10 KidsGEQ proposed by Poels et al. (2008)

Kids GEQ Dimensions		Statements (Questionnaire)
#1	Challenge	1.) It was exciting.
		2.) I felt challenged by the game.
		3.) I had to put a lot of effort into the game.
#2	Competence	4.) I felt confident while playing.

Kids GEQ Dimensions		Statements (Questionnaire)
		5.) I felt competent/capable.
		6.) I was good at it.
#3	Flow	7.) I paid a lot of attention to the game.
		8.) While playing, I forgot everything around me.
		9.) I felt like I was inside the game.
#4	Immersion	10.) I could use my fantasy in the game.
		11.) I found the game impressive.
		12.) The game was beautiful.
#5	Negative Affect	13.) It was a stupid game.
		14.) I found it tiresome/exhausting.
		15.) I felt bored.
#6	Positive Affect	16.) The game made me laugh from time to time.
		17.) I thought it was fun to play the game.
		18.) I felt good while playing.
#7	Tension	19.) Playing the game did not go as I wanted to.
		20.) The game made me nervous/tense/very uneasy.
		21.) I have grumbled/complained while playing the game.

However, the tool used for the survey method by KidsGEQ typically relies on scaling technique. It employs 5-point Likert scale: *Not (0) – Very little (1) – A bit (2) – Fairly (3) – A lot (4)* to measure the degree of children's feeling when playing digital games. It is commonly known that Likert scales are prone to a response bias as children may answer in the way they believe it can appease the person (especially an authority figure) administering the survey (Bruck, Ceci, & Melnyk, 1997); they tend to be overly positive and give the highest scores on the scale. This issue has been taken into account by applying a Visual Analogue Scale (VAS). Such pictorial representations are more appealing than plain words, and are suitable for children aged 7 and older to identify their feelings or opinions (Shields, et al., 2003). Besides, the scale is fully labelled to

enable children to give more reliable responses (Read. & Fine, 2005). Read and her colleagues (2002; 2005; 2006) introduced the *Smileyometer* which based on a 1-5 Likert scale to measures how children experience on the product. I designed my own smiley faces (Figure 7.3, Figure 7.4 and Figure 7.5) inspired by the Smileyometer of Read, MacFarlane, and Casey (2002). The smiley faces are on a simple scale, added by words and presented in a horizontal row. Each face represents child's perceived level of their feeling on digital games. The visual analog scale was already modified according to the external reviewers' comments to make them match tightly the scale description, for example, the mouth of "2" is a line which does not match disagreement (better would be less sad mouth than for "1"). The reviewers concerned that this mismatch has very much likely caused a bias in the data. The visual analog scale after modifying is illustrated as Figure 7.3.

Not at all	Very little	Quite	Fairly	Very much
(0)	(1)	(2)	(3)	(4)

Figure 7.3 VAS for evaluating the games experience measured by KidsGEQ

To contribute children to identify their feelings or opinions, the 5-point Likert scales of KidsGEQ was associated by the visual analogue scale. The KidsGEQ statements and the VAS were implemented as an online questionnaire, which was integrated into the games. The children could indicate how they felt while playing the games by rating each of the statements with the visual analogue scale. The study was conducted in the presence of the researcher and teachers, who were prompt through the time of each empirical study to give support (e.g., reading out the statements; explaining certain words) when needed. However, after the Pilot Test (Section 6.2.2.3), the KidsGEQ was administered to probe the user friendliness and understandability of the statements and the VAS. Children had no problems understanding the KidsGEQ but generally found that some words of KidsGEQ statements were too difficult for them such as competent, tiresome, nervous, and grumbled. Therefore, I made some changes of the words; the alternative words were put together with the original words such as

"competent/capable", "tiresome/exhausting", "nervous/tense/very uneasy", and "grumbled/complained". Likewise, some description of the original scale was slightly confusing, for example, *A bit (2)* – and – *A lot (4)*, it was finally modified to *Quite (2)* – and –*Very much (4).*

7.2.11 Results and Discussions

The two DEGs were compared in terms of their experiential. A between-subjects design was employed with the game design being the independent variable.

To evaluate H2a, the children's responses to 21 statements covering the 7 dimensions of gameplay experience were analysed. Each dimension comprised 3 statements (Table 7.10); the mean of each dimension was computed over its constituting items and over all the children in the respective group. Then, the differences in the average gameplay experience ratings as represented by each of the dimensions between the two groups were compared (Table 7.11).

Table 7.11 Comparing the ratings on the dimensions of KidsGEQ by the two groups

GAME	**FoodGroups-A**			**FoodGroups-B**			**Statistics**	
Dimensions	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**U**	***p***
#1 Challenge	2.53	59	1.02	2.48	67	1.05	-.106	.916
#2 Competence	3.25	59	.81	2.90	67	.68	-3.573	.000**
#3 Flow	2.75	59	1.02	2.36	67	.98	-2.313	.021*
#4 Immersion	2.53	59	1.07	1.98	63	1.03	-2.871	.004*
#5 Negative Affect	.98	59	1.08	1.31	64	.77	-2.854	.004*
#6 Positive Affect	2.79	59	1.07	2.13	64	1.06	-3.506	.000**
#7 Tension	1.07	59	1.06	1.34	64	.99	-1.965	.049*

Table 7.12 Comparing the ratings on the dimensions of KidsGEQ and children's gender by the two groups

GAME	FoodGroups-A								FoodGroups-B							
	girl			boy			Statistics		girl			boy			Statistics	
Dimensions	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**U**	***p***	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**U**	***p***
#1 Challenge	2.83	32	.88	2.16	27	1.06	-2.41	.016*	2.73	40	.83	2.11	27	1.23	-1.96	.049*
#2 Competence	3.44	32	.54	3.01	27	.99	-1.65	.099	2.94	40	.55	2.84	27	.83	-.01	.990
#3 Flow	3.00	32	.89	2.45	27	1.08	-1.88	.060	2.67	40	.77	1.88	27	1.07	-3.12	.002*
#4 Immersion	2.69	32	1.04	2.32	27	1.09	-1.40	.161	2.16	39	.93	1.67	24	1.11	-1.95	.051
#5 Negative Affect	.85	32	.95	1.12	27	1.20	-.77	.436	1.26	40	.75	1.38	24	.81	-.88	.377
#6 Positive Affect	2.93	32	1.03	2.60	27	1.11	-1.38	.167	2.26	40	.96	1.88	24	1.19	-1.10	.269
#7 Tension	.97	32	1.07	1.17	27	1.05	-.89	.372	1.38	40	.98	1.26	24	1.00	-.52	.603

As most of the ratings do not follow the normal distribution, as the results of Shapiro-Wilk tests where all except two Sig. values are smaller than 0.05, non-parametric Mann-Whitney tests were used to compare the group differences.

The results, as shown in Table 7.11, indicate that the means for the dimension #1, #2, #3, #4 and #6 of FoodGroups-A were higher than those of FoodGroups-B, whereas dimension #5 and #7 were lower than those of FoodGroups-B. There were *significant differences* in the perceptions of these 6 dimensions of gameplay experience between the two groups of children: *Competence*; *Flow*; *Immersion*; *Negative Affect*; *Positive Affect*; *Tension*. However, there was no significant difference in *Challenge*. The results are discussed according to each dimension of KidsGEQ in the following.

Challenge: Elliott and Dweck (1988) and Nicholls (1984) stated that children with learning goals attempt to increase their efficacy to understand or master something new. KidsGEQ specifies that a game can elicit a feeling of being challenged if children have to put a lot of effort into the game. The data showed that there was no significant difference in challenge between FoodGroups-A and FoodGroups-B ($U = -.11$, $n_A = 59$, $n_B = 67$, $p > .05$) because both games were designed by following DEG-7-11#1. It can be inferred that a clear presentation of a learning goal can enhance the feeling of being challenged.

However, there were significant differences in the rating on the dimension of *Challenge* between the genders (Table 7.12). Girls who played FoodGroups-A felt more challenged to play the game than boys. The result was same as girls who played FoodGroups-B. Whereas, boys felt that they used less effort than girls to win the games. The games were less challenging or less exciting for them.

Competence: KidsGEQ specifies that a game can enhance the feeling of competence if children feel confident while playing it. Guidance or instructional support makes children feel *confident* to play. They can find the examples of how to get correct answers from the instruction rather than only relying on the games (Moreno & Mayer, 2005; Swaak & De Jong, 2001). However, the data showed that children felt more competent to play FoodGroups-A than FoodGroups-B ($U = -3.57$, $n_A = 59$, $n_B = 67$, $p < .05$) in spite of both FoodGroups-A and FoodGroups-B were designed by following DEG-7-11#2. It can be inferred that providing proper instruction is not the only feature of a DEG that makes children feel competent, but other features are also needed to make them feel good about the game, such as feedback that allows them to know their progress/competence (DEG-7-11#8), a game which incorporates reminders or hints that make children recall information for playing and winning the game (DEG-7-11#6).

Flow: KidsGEQ specifies that a game can enhance the *flow* feeling if they pay a lot of attention to it. As mentioned in Section (ii), a game, which is chunked into levels, has distinctive features in each level. These different features can draw the children's attention to play. Thus, FoodGroups-A which was designed by following DEG-7-11#5 could induce higher flow than FoodGroups-B ($U = -2.31$, $n_A = 59$, $n_B = 67$, $p < .05$). Furthermore, there was significant difference in the rating on the dimension of *Flow* between genders (Table 7.12). Boys who played FoodGroups-B felt less attentive to play the game than girls did. FoodGroups-B which was not designed by following DEG-7-11#5, there is only one level, could not induce the attention from boys to play. It is also consistent with the opinion on the dimension of *Challenge* that boys felt that FoodGroups-B was less challenging or less exciting for them to play.

Moreover, FoodGroups-A followed DEG-7-11#3, enabling children to have their own avatar which they can somewhat represent themselves, thereby developing a stronger sense of being inside the game according to Statement#9 of KidsGEQ (Table 7.10) asked; this contributes to the emotion of *flow* as specified by KidsGEQ. Moreover, the result in Table 7.20) and the report of Steiner, et al. (2009) also supports that the

different genders prefer to select their own favorite character according to their own gender.

Immersion: Children *immerse* if the game is beautiful, impressive and fancy, as specified in KidsGEQ. FoodGroups-A, which followed DEG-7-11#7, could make the children feel more immersed than FoodGroups-B ($U = -2.87$, $n_A = 59$, $n_B = 63$, $p < .05$). Cartoon-like animation in FoodGroups-A could enhance children aged 7-11 years fantasy, as discussed in the literature review above. Moreover, the children could find it more impressive because FoodGroups-A addressed the issue of gender difference (Boyle & Connolly, 2009), by providing them the options to select their own favourite characters (DEG-7-11#3).

Negative Affect: The result suggested that FoodGroups-B elicited more negative affect than FoodGroups-A ($U = -2.85$, $n_A = 59$, $n_B = 64$, $p <. 05$). KidsGEQ specifies that children have negative affect if they find game tiresome or exhausting. It can be explained by the fact that FoodGroups-B did not include cues or signals to remind children of the conceptual basis for the previous rule or knowledge as suggested by DEG-7-11#6. Children might be hesitant while playing because no hints were provided. They did not feel confident while playing, and thus had negative gameplay experience.

Positive Affect: Rewards and even punishments, when delivered in a timely and engaging manner, can lead to *positive emotions* (Wang & Sun, 2011). FoodGroups-B did not follow DEG-7-11#8, no rewards and punishments provided as feedback to inform children about their progress, so it could not get positive affect as FoodGroups-A did ($U = -3.51$, $n_A = 59$, $n_B = 64$, $p < .05$).

Moreover, from the literature reviews part, apart from the strategy of chunking, associating and repeating information (DEG-7-11#5), helping players build up background knowledge in lower levels can facilitate them to resolve challenges in higher levels, a meaningful context must be provided for effective encoding of information, such as using techniques of cued recall (DEG-7-11#6). Those designs could help to enhance positive gameplay experience as well.

Tension: The data indicated that children felt tenser to play FoodGroups-B than FoodGroups-A ($U = -1.97$, $n_A = 59$, $n_B = 64$, $p < .05$). To play FoodGroups-B, which did not follow DEG-7-11#4, children needed to race with speed and time that might cause them *tense*, nervous, or very uneasy, as specified by KidsGEQ.

7.2.12 Summary

Overall, H2a is rejected because of the significant differences in gameplay experiences as measured by KidsGEQ found. There was a clear indication that the children had higher preference for FoodGroups-A. Both FoodGroups-A and FoodGroups-B were perceived to be challenging, but FoodGroups-A was slightly more challenging and could induce higher flow, immersive feeling and positive affect. The children who played FoodGroups-A felt more competent than their counterparts who played FoodGroups-B did. Also, the children playing FoodGroups-B felt tenser and had negative affect. In summary, FoodGroups-A is more preferable for the sample of primary school children involved in the study.

7.2.13 Measure 2: Gameplay experience measured by the child-friendly statements derived from the GameFlow model

Children were asked to complete another post-gameplay experience questionnaire. As the games were designed based on the DEG-7-11 v1 heuristics which were derived from the GameFlow Model, thus, to validate the effectiveness of DEG-7-11 v1, I evaluated the games with reference back to the GameFlow model. Gameplay experience was evaluated by the statements derived from the GameFlow model.

The study was aimed to verify a null hypothesis (H):

H2b: There are no significant differences in gameplay experience as measured by the statements derived from the GameFlow model between two groups of children aged 7-11 years who played one of the two games independently.

7.2.14 Apparatus

The GameFlow model of Sweetser and Wyeth (2005) consists of 8 elements of which 7 were applied in this study, because the element ‘Social Interaction’ was irrelevant, given that FoodGroups games were designed to play individually (see Chapter 4, Table 4.1).

The criteria of the GameFlow model were translated into a set of 16 statements understandable for children who were the evaluators, that is why it was called the child-friendly version of the GameFlow model (Table 7.13). There were steps to change the criteria to simple statements. Following shows the example of how the statements were

derived.

First, the main criteria of each element of the GameFlow model were mapped to specific game features, such as a criterion says "Games can captivate players' concentration by providing *stimuli* that are worth attending to. *Stimuli* are always in multiple forms (e.g., sound, animation, graphics, and speech)…" (detailed in Table 4.1), the word "*stimuli*" were mapped to game features like "pictures, colours, text, animation effects, etc.". These features were then incorporated in derived statements, such as "I liked the *pictures* which were clear and meaningful.", "My eyes were comfortable because the *text* size was easy to read.", etc. The statements were used by children to evaluate the games features. The main criteria usually used technical terminologies, such as "Players should feel a *sense of control* over their characters in the game world...", these were translated into plain words and incorporated in statements like "I knew *how to control* the movement of the chef." The statements were modified to ensure that the language is child-friendly. Positive questions were used instead of negative questions which might be confusing for young children. For instance, "I was able to know immediately if I made a right or wrong decision." was used instead of "I was *unable* to know if I made a wrong decision.".

Consequently, there were different numbers of statements per element, as there is not always one-to-one correspondence between criterion and statement. An element might contain only one main criterion whereas the other contains more than one main criteria. All of the child-friendly statements derived from the GameFlow model are displayed in Table 7.13.

The idea of translating based on the recommendation of Read and Fine (2005). As Read and Fine (2005) discussed four common issues of using survey methods with children: Two are related to children's temperament and cognition, and the other two are children's age and their language and the design of the questions - answers. To address the issues, Read and Fine (2005) proposed a set of guidelines which were applied in this study, especially using child-friendly language and positive questions.

The statements were then implemented as an online questionnaire, which was integrated into the games. After playing the games, the children could indicate what they thought about the games by rating each of the statements with a visual analogue scale (Figure 7.4).

Awful Poor Neutral Good Brilliant

Figure 7.4 Visual analogue scales for evaluating the gameplay experience measured by the child-friendly statements derived from the GameFlow model

Not only the close-ended questions but also open-ended questions were used in the questionnaires. The children were also asked to describe their likes, dislikes, problems and improvement suggestions about the games in the given text boxes. For some of the younger children (7-8 years old), the questions were read out loud by the teacher, and the children's oral responses were typed in for them.

Table 7.13 the child-friendly statements derived from the GameFlow model

GameFlow model Elements		**child-friendly Statements**
#1	Concentration	1.) I liked the pictures which were clear and meaningful.
		2.) I liked the colours used in the game.
		3.) My eyes were comfortable because the text size was easy to read.
		4.) I liked the animation effects (e.g. speed, timing).
#2	Challenge	5.) I liked that the game provided me different levels of challenge.
		6.) The game moved from the easier to harder levels. It helped me remember the food groups.
		7.) When I moved to the higher levels, mice ran in; I liked them because they made it more challenging.
#3	Player Skills	8.) I was able to start playing the game without reading the manual first.
		10.) While playing the game, the help button was useful.
#4	Control	9.) It was easy to play, just clicking the mouse or hitting the keyboard.
		11.) I knew how to control the movement of the chef.
#5	Clear Goals	12.) The overall goal of the game was clear at an early stage.

GameFlow model Elements		child-friendly Statements
#6	Feedback	13.) I was able to know immediately if I made a right or wrong decision.
		14.) It was good to know my score all the time during the game.
#7	Immersion	15.) I liked to monitor the chef to collect a food box and avoid a mouse at the same time. It made me attentive.
		16.) I found the colours useful for me to remember the food groups.

7.2.15 Results and Discussions

To evaluate H2b, the children's responses to 16 statements covering the 7 dimensions of gameplay experience were analysed. Each dimension comprised different number of statements (Table 7.13); the mean of each dimension was computed over its constituting items and over all the children in the respective group. Then, the differences in the average gameplay experience ratings as represented by each of the dimensions between the two groups were compared (Table 7.14).

As all the *p* values of the Shapiro-Wilk tests were smaller than 0.05, indicating the data were not normally distributed, non-parametric tests were then used to evaluate H2b.

Table 7.14 Comparing the ratings on the child-friendly statements of the two groups

GAME	FoodGroups-A			FoodGroups-B			Statistics	
Dimensions	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**U**	***p***
#1 Concentration	4.31	58	.69	3.86	65	.81	-3.414	.001*
#2 Challenge	4.05	58	.92	3.72	65	1.00	-2.009	.044*
#3 Player Skills	4.09	57	.83	3.92	64	1.08	-.467	.640
#4 Control	4.31	57	.72	4.17	64	1.00	-.205	.838
#5 Clear Goals	4.43	56	.91	4.14	63	1.16	-1.256	.209
#6 Feedback	4.11	56	.96	3.60	63	.98	-3.174	.002*
#7 Immersion	4.03	56	1.02	3.57	63	1.00	-2.827	.005*

Table 7.15 Comparing the ratings on the dimensions of the child-friendly statements and children's gender by the two groups

GAME	FoodGroups-A								FoodGroups-B							
	Girl			boy			Statistics		Girl			boy			Statistics	
Dimensions	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**U**	***P***	**Mean**	**N**	**Std.**	**Mean**	**N**	**Std.**	**U**	***p***
#1 Concentration	4.39	32	.69	4.21	26	.67	-1.27	.201	4.00	39	.62	3.64	26	.99	-1.17	.240
#2 Challenge	4.20	32	.79	3.85	26	1.04	-1.22	.222	3.87	39	.80	3.50	26	1.21	-.61	.536
#3 Player Skills	4.12	31	.81	4.03	26	.85	-.39	.693	4.00	38	.85	3.80	26	1.34	-.01	.994
#4 Control	4.19	31	.74	4.44	26	.66	-1.29	.197	4.23	38	.91	4.07	26	1.12	-.19	.848
#5 Clear Goals	4.41	31	.88	4.44	25	.96	-.12	.900	4.11	36	1.08	4.18	27	1.27	-.79	.425
#6 Feedback	4.24	31	.72	3.94	25	1.17	-.65	.514	3.68	36	.80	3.48	27	1.18	-.12	.897
#7 Immersion	4.17	31	.84	3.84	25	1.19	-.86	.385	3.69	36	.84	3.40	27	1.17	-.55	.577

Table 7.14 showed that the means for all dimensions of FoodGroups-A were higher than those of FoodGroups-B. There were *significant differences* in the perceptions of these 4 dimensions of gameplay experience between the two groups of children: *Concentration*; *Challenge*; *Feedback; Immersion*. However, there were no significant differences in the other 3 dimensions: *Player Skills*; *Control*; *Clear Goals*. The results are discussed according to each dimension of the GameFlow model in the following.

Clear Goals: According to the GameFlow model, games should provide the player with *clear goals* at appropriate times. Likewise, Pagulayan et al. (2003) suggested that the goals of a game should be conveyed clearly. The data showed that there was no significant difference in *Clear Goals* between FoodGroups-A and FoodGroups-B ($U = -1.256$, $n_A = 56$, $n_B = 63$, $p > .05$). It is because both games were designed by following DEG-7-11#1. Regarding to the rating on Statement#12 which derived from the element of *Clear Goals* of the GameFlow model (Table 7.13), children perceived that either FoodGroups-A or FoodGroups-B provided them with clear goals at an early stage. It was consistent with the rating on Statement#10 which derived from the element of *Player Skills*, the provided help button could be perceived as useful while playing the games.

Player Skills: Children need guidance to understand the principles of a learning technology (Rieber & Rieber, 2005). The GameFlow model proposes that a game should support player skill mastery. Players should have adequate information to start playing game. The way players are taught to play the game is crucial to their skills development and enjoyment of the game. Thus, the game should include help or manual. So that, both FoodGroups-A and FoodGroups-B were designed by following DEG-7-11#2. The empirical study showed that there was no significant difference in Player Skills between FoodGroups-A and FoodGroups-B ($U = -.467$, $n_A = 57$, $n_B = 64$, $p > .05$). According to the rating on Statement#8 and Statement#10 which derived from the element of *Player Skills* of the GameFlow model (Table 7.13), children perceived that either FoodGroups-A or FoodGroups-B provided them with help button and manual which were useful while they were playing the game.

Control: The GameFlow model states that the game should be designed to allow players feel a sense of control over games' characters in the game word. According to the rating on Statement#9 and Statement#11 which derived from the element of *Control* of the GameFlow model (Table 7.13), children who played either FoodGroups-A or

FoodGroups-B confirmed that they knew how to control the games such as controlling the movement of the chef. Thus, there was no significant difference in Control between FoodGroups-A and FoodGroups-B ($U = -.205$, $n_A = 57$, $n_B = 64$, $p > .05$).

Immersion: The data indicated that the children who played FoodGroups-A felt more immersed than their counterparts who played FoodGroups-B ($U = -2.827$, $n_A = 56$, $n_B = 63$, $p < .05$). Regarding to the rating on Statement#15 which derived from the element of *Immersion* of the GameFlow model (Table 7.13), children still felt immersed even they needed to monitor the chef to collect foods together with avoid mice. Instead of making them confused, the game made them attentive. It was likely because FoodGroups-A followed DEG-7-11#4. The game did not provide any high pressure such as very fast-run mouse or time limit. The game has features of relaxation such as having minimalistic interfaces, appropriate speed, and no time pressure. The GameFlow model specifies that games should help people to calm down. Also, it mentioned by several research studies (see literature reviews) that games with minimalistic interfaces and short-term commitments can promote relaxation.

Moreover, regarding the rating on Statement#16, children agreed that the colours FoodGroups-A provided were useful for them to remember the food group. It can be referred that they could use the colours as reminder to play continually without interruption, it made them immersed.

Challenge: As mentioned early in literature review, chunking a game into multi-levels can induce children who do not prefer short and easy games. The result of the empirical study showed that the children who played FoodGroups-A perceived more challenged than their counterparts who played FoodGroups-B did ($U = -2.009$, $n_A = 58$, $n_B = 65$, $p < .05$). It can be referred that because FoodGroups-A followed DEG-7-11#5. Regarding to the rating on Statement#5, Statement#6, and Statement#7 which derived from the element of *Challenge* of the GameFlow model (Table 7.13), children preferred that FoodGroups-A provided them different levels of challenge and the game progressed from the easier to harder levels, it helped them remember the food groups, furthermore, when they progressed to the higher levels, mice ran in which they liked because the mice made the game more challenging. Likewise specified by the GameFlow model, a game should provide new challenges at an appropriate pace. It should be sufficiently challenging and matches the players' skill level. The level of challenge should increase as the player progresses through the game.

Concentration: The GameFlow model specifies that to be enjoyable, a game requires concentration. Games can captivate players' concentration by providing stimuli that are worth attending to. One interesting stimulus is animation. From the literature review, cartoon-style of animation is much familiar and their expressions are more understandable to children. The data showed that children playing FoodGroups-A had a higher level of concentration than children playing FoodGroups-B ($U = -3.414$, $n_A = 58$, $n_B = 65$, $p < .05$). It can be referred that because FoodGroups-A was designed by following DEG-7-11#7, cartoon-like animations were used in the game. According to the rating on Statement#4 which derived from the element of *Concentration* of the GameFlow model (Table 7.13), children liked the animation effects used in FoodGroups-A. Moreover, children preferred more the clear and meaningful pictures, colours, and text style used in FoodGroups-A than that of FoodGroups-B as asking in Statement#1, Statement#2, and Statement#3.

Feedback: From the literature reviews above, motivation can be sustained through methods such as feedback, reflection, and active involvement. The data suggested that there was significant difference in preference of feedback that the games provided ($U = -3.174$, $n_A = 56$, $n_B = 63$, $p < .05$). According to the rating on Statement#13 and Statement#14 which derived from the element of *Feedback* of the GameFlow model (Table 7.13), children felt good to know their score all the time during playing FoodGroups-A. They were able to know immediately if they made a right or wrong decision. FoodGroups-B did not follow DEG-7-11#8, no score as feedback to inform children about their progress, so it could not get preference as FoodGroups-A did.

7.2.16 Summary

Overall, H2b is rejected because of the significant differences in gameplay experience as measured by the child-friendly statements derived from the GameFlow model found. There was a clear indication that the children had higher preference for FoodGroups-A. The children who played FoodGroups-A felt more *concentrated*, *challenged*, and *immersed* than their counterparts who played FoodGroups-B. Also, the children preferred *feedback* that FoodGroups-A provided than FoodGroups-B did. However, children preferred *clear goals*, *player skills*, and *control* which both FoodGroups-A and FoodGroups-B provided. In summary, FoodGroups-A is more

preferable for the sample of primary school children involved in the study.

7.2.17 The correlation between the two measures of gameplay experience

This study aimed to investigate the association of the two measures used to measure gameplay experience (Section 7.2.9 and Section 7.2.13). If there was correlation between the two measures, it can convince that the gameplay experience of the two games are trustful.

This study was aimed to verify a null hypothesis (H):

H3: There is no significant correlation between the two measures of gameplay experience.

7.2.18 Results and Discussions

To evaluate H3, the correlations between the values of the KidsGEQ rating and the child-friendly statements (derived from the GameFlow model) ratings were computed. The children's responses to 21 statements of gameplay experience (KidsGEQ) were analysed. The sum of all 21 statements was computed over all the children in the respective group. Likewise, the children's responses to 16 child-friendly statements of gameplay experience (derived from the GameFlow model) were analysed. The sum of all 16 statements was computed over all the children in the respective group.

As all the p values of the Shapiro-Wilk tests were smaller than 0.05, indicating the data were not normally distributed, non-parametric tests were then used to evaluate H2. The Spearman correlation coefficient between the two variables was computed.

The result shows that there is a highly significant correlation between the two measures of gameplay experience ($N = 125$, $r_s = .628$, $p < .01$). It implies that the higher the values of the KidsGEQ rating, it is more likely that the child-friendly statements (derived from the GameFlow model) ratings will have a higher value.

7.2.19 Summary

There are some elements of the child-friendly version of the GameFlow model that are repetitive to some dimensions of KidsGEQ, such as *challenge*, *immersion*. Moreover, some element and dimension is very close, such as element of *concentration* and dimension of *flow*. The analysis results found that the dimensions or elements of

'challenge' and 'immersion', which are covered in both KidsGEQ and the child-friendly version of the GameFlow model could identify the same result that is the children who played FoodGroups-A felt more *challenged* and *immersed* than their counterparts who played FoodGroups-B did.

While the child-friendly version of the GameFlow model mainly evaluates gameplay experience in games, some elements could be used to evaluate games usability such as elements of *clear goals*, *player skills*, *control*, and *feedback*. Those elements contribute a game is playable. Without goals (*clear goals*), instructions (*player skills* and *control*), the game is not playable. Both games provides children with goals and instructions, the analysis results also showed that both FoodGroups-A and FoodGroups-B provided children with *clear goal*, *player skill* and *control* and children preferred the elements the games provided.

Regarding the implication, it can be concluded that not only the child-friendly version of the GameFlow model can evaluate gameplay experience but also it can be used to evaluate games usability, especially, the element of clear goal, player skill, control, and feedback. Accordingly, I have categorized DEG-7-11#1 (learning goals) and DEG-7-11#2 (instructive and multimodal instruction) as *essential heuristics* (Section 6.2.1.1) in the sense that they must be followed so that a game can be qualified as a DEG. The result of the analytic evaluation can demonstrate that these two heuristics are needed for a DEG designing; without applying them a game will probably have lower preference.

7.2.20 Method 2: Validation of DEG-7-11 v1 by Children Rating

As DEGs are essentially games in which learning content is integrated to facilitate learning, in principle all game types are relevant. Accordingly, the eight proposed heuristics of DEG-7-11 v1 should be broadly applicable to games that children aged 7-11 years normally play. In order to investigate the children's agreement on the DEG-7-11 v1 heuristics, the eight heuristics were translated into understandable statements by children. The eight statements were then integrated into gamepaly questionnaire mainly in the *General opinions on educational games Part*. Then, children were asked to rate these statements, which might be based on their previous experience with such games or on their projection of experience with other games. The whole pre-gameplay process took about 15 minutes. The two demographic variables – age and gender – could play a role in the opinions examined.

7.2.21 Apparatus

7.2.21.1 The child-friendly statements converted from DEG-7-11 v1 for Attitude opinions measure

As the DEG-7-11 v1 heuristics are the first version of the set of guidelines for designing DEGs for children, it contains some technical wordings which are not understandable by children. Thus, the heuristics of DEG-7-11 v1 were converted into a set of simple statements, which is more perceptive to children. There were steps to change the heuristics to simple statements. In the following text some examples of how the statements were changed are presented.

Firstly, the key meaning of the heuristic was captured, I do not want to burden children (especially the 7-years-old) by reading too much information, some modifier wordings or phrases in the heuristics statement are omitted, such as DEG-7-11#5: "*A DEG should be separated into multi-levels with…enabling children to practice new information by performing similar tasks.*" and left only "initial levels being disguised tutorials". Secondly, the technical terminologies were translated into plain words, such as "initial levels" to "lower levels" and "disguised tutorials" to "basic knowledge". Then, the statements were modified to ensure that the language is child-friendly, such as "…initial levels being disguised tutorials…" is changed to "Lower levels give a basic knowledge…". Positive questions were used because negative questions might be confusing for young children. For instance, for S2 of DEG-7-11#2, "An educational game should be easy to play without having to read a manual or any help text." was used instead of "Children aged 7-11 *do not* need a supported instruction when playing a DEG, it should be easy to play.". Table 7.16 compiles DEG-7-11 v1 statements and the child-friendly version of DEG-7-11 v1.

Table 7.16 the child-friendly statements converted from the heuristics of DEG-7-11 v1

DEG-7-11 v1 statement	the child-friendly version of DEG-7-11 v1
#1: Instead of setting a goal on scoring like entertainment games, for a DEG, a specific learning goal should be set. Also, the goal should be clear, concise, simple, and presented early in the DEG.	S1: The instructions should make me understand the main goal of the game.
#2: Children aged 7-11 years should be supported by instruction when playing a DEG, the instruction should explain how to get correct answers, but without relying on text-based manual only.	S2: An educational game should be easy to play without having to read a manual or any help text.
#4: A DEG for children aged 7-11 years should be relaxing to play by having minimalistic interfaces, appropriate speed, and no time pressure.	S3: An educational game should be relaxing to play.
#5: A DEG should be separated into multi-levels with initial levels being disguised tutorials, enabling children to practice new information by performing similar tasks.	S4: Lower levels of a game should give me basic knowledge for playing its higher levels.
#6: A game should incorporate reminders or hints that children can use for recalling information from their memory.	S5: An educational game should provide different ways to learn a topic rather than just present information.
#8: Rewards and punishments should be provided in the form of in-game feedback interfaces; they are incentives and can inform children aged 7-11 years about their progress and learning.	S6: An educational game needs to provide in-game feedback such as sound effects, rewards and scores to make me aware of my progress.

Six heuristics of DEG-7-11 v1 (Table 7.16) were translated into statements. The statements were used for testing attitude opinions. The statements were then digitalized as an online questionnaire - a more engaging format than traditional pen-and-paper for the children and also eased data analysis for me.

Then, prior to the validation study, the understandability of the questionnaire was pilot tested with four children (2 boys and 2 girls; an average age of 9.25 years old). The statements were then modified based on their feedback. Furthermore, a Visual

Analogue Scale (VAS) was used (see Figure 7.5). The following instructions are presented in two consecutive pages: "*Tell us your general opinion of educational games that help you learn something and have fun at the same time*." (click  to the following page) "*You'll see a set of 10 statements in next screens. Please indicate how you feel on each of them by clicking one of the numbers in the scale below*."

Figure 7.5 Visual analogue scales for evaluating the child-friendly version of DEG-7-11 v1

7.2.21.2 DEG-7-11 v1 Implementation to game feature for Behavioural measure

For DEG-7-11#3 and #7, I differently used behavioural measure to provide evidence. I observed from behavioural evidence while and after children playing game.

To validate DEG-7-11#3, *One single DEG could suit different genders so that children can select or create their own favourite avatar*, the data from playing game was used. As FoodGroups-A was designed to have two options of characters which children could select their own favourite one. The data of the selection was counted and compared.

Figure 7.6 "Choose Your Character" used for evaluating DEG-7-11#3

To validate DEG-7-11#7, *Statement#4* of the child-friendly version of the GameFlow model (Section 7.2.13) was used, see Table 7.17. The two game prototypes were designed differently in terms of animation effects. FoodGroups-A was designed by using cartoon-like animation, whereas FoodGroups-B was designed by using less cartoon-like animation but rather more static cartoon-like. After playing game, children were asked to rated the preference by *Statement#4*. It is assumed that if children liked the animation effects of FoodGroups-A, it means they agreed with the benefit of cartoon-like animations which specified in DEG-7-11#7.

Table 7.17 Statement#4 of the child-friendly version of the GameFlow model used for validating DEG-7-11#7

DEG-7-11#7	Statement#4
Animations can influence learning for children aged 7-11 years, especially cartoon-like animations can enhance imagination and fun, resulting in playful learning.	I liked the animation effects (e.g. speed, timing).

7.2.22 Results and Discussions

The means and medians for each of the six statements over all children were computed (Table 7.18). The correlations between the values of demographic variables and the ratings of the statements were then computed (Table 7.18; Table 7.19). As the datasets are not normally distributed as indicated by Shapiro-Wilk test ($p < .05$), non-parametric statistical tests, including Spearman's rank correlation coefficient which used to measure of association between each statement and children's age and Mann-Whitney U test which used to compare differences of the opinion between children's gender and between their game experience, were used.

Table 7.18 Agreement ratings (1: strongly disagreed; 5: strongly agreed) on the six statements (N =182)

	Statement (S)					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Mean	4.13	3.26	3.96	3.84	3.84	4.01
Median	5.00	3.00	4.00	4.00	4.00	4.00
Std	1.123	1.327	1.136	1.168	1.047	1.085
r_s (age)	.025	.043	-.014	.049	-.012	.150
p	.738	.564	.853	.515	.867	.043*
* Spearman's correlation coefficient is significant at $p < 0.05$						

Table 7.19 Opinions on the six statements group by children' gender and game experience

	GENDER						**GAME EXPERIENCE**					
	girl (n = 104)		**boy** (n = 78)		**Statistics**		**low** (n = 71)		**high** (n = 111)		**Statistics**	
	Mean	**Std.**	**Mean**	**Std.**	**U**	***p***	**Mean**	**Std.**	**Mean**	**Std.**	**U**	***p***
S1	4.16	.94	4.08	1.32	-.723	.469	4.20	1.11	4.08	1.12	-.732	.464
S2	3.16	1.29	3.38	1.37	-1.212	.225	3.21	1.39	3.29	1.28	-.255	.798
S3	3.85	1.08	4.10	1.19	-2.091	.036*	3.86	1.13	4.02	1.13	-1.099	.272
S4	3.93	1.08	3.71	1.27	-1.035	.301	3.89	1.21	3.80	1.14	-.723	.470
S5	3.87	.95	3.81	1.16	-.036	.972	3.85	1.14	3.84	.98	-.430	.667
S6	4.01	.93	4.00	1.26	-.878	.380	4.01	1.04	4.00	1.11	-.081	.935
* Mann-Whitney U test is significant at $p < .05$												

In the following text, the results per statement were reported and keywords of each statement were used as sub-section headings.

- ***S1: Understand main goal***

There was no significant correlation between the children's age and their rating of S1. Gender and their game experience were not significant variables either. Clearly, children need to know the main goal in order to prepare themselves to complete the game, as Driscoll (2005) referred to Event 2 of Gagné's instructional event - "Informing the learner of the objective" implies that expectancy on what is to learn influences how learners are aware of and prepare themselves to learn certain information. Also, as mentioned in literature review in Section (i). Clement (1961) stated that making students conscious of the learning goal can enhance their learning success. Hence, applying this concept to the design of DEGs, it is thus recommended that the main goal of the game should be presented before the game is started.

- ***S2: Manual and help text***

None of the demographic variables played any significant role in influencing the ratings of S2. Generally speaking, children aged 7-11 years were *neutral* with regard to reading a manual or any help text. On the other hand, it is clear when playing the game children often need timely information how to proceed with gameplay. Nonetheless, one should not rely on text-based instructions, but consider using different modalities such as audiovisual instructions.

As it has no evidence that the children aged 7-11 years reject instructions, designers can assume that manual is still required for a DEG. It should be provided an on-demand basis, but it should not be long.

- ***S3: Relaxing to play***

There was significant difference in the rating of S3 between gender ($U = -2.091$, $n_{girl} = 104$, $n_{boy} = 78$, $p < .05$). Girls rated S3 less (mean = 3.85; median = 4.00) than that of boys (mean = 4.10; median = 5.00). However, it was found that girls agreed and boys strongly agreed with the statement. It can be said that both genders *agreed* that an educational game should be represented in a relaxing way to facilitate immersion.

- ***S4: Link between lower level and higher level***

None of the demographic variables were found to be significant factors for the ratings of S4. Most of the children *agreed* that lower levels should provide them with some basic information for playing higher levels. As children assume that a DEG can

help them learn something, each level of a game should provide them with relevant information systematically. Designers can utilize the multi-level approach to gradually release information to children and help them learn incrementally.

- ***S5: Different ways to learn***

None of the demographic variables were found to be significant factors in influencing the ratings of S5. Most children *agreed* that just presenting information is not enough. To gain learners' attention, it is necessary to apply different strategies (e.g., both visual and verbal information (Clark & Paivio, 1991; Glenberg, Gutierrez, Levin, Japuntich, & Kaschak, 2004)) as they can promote better remembering and learning information. Pictures, colour-coding, cues and signals can help recall previous knowledge (Levin, 1979; Mayer & Gallini, 1990; Spence, Wong, Rusan, & Rastegar, 2006).

- ***S6: In-game feedback***

There was a very weak positive correlation between S6 and children's age, which was statistically significant (r_s(age) = 0.150, $p < 0.05$). The result suggests that the older the children, the more they tend to need in-game feedback.

Age was found to be significant factors in influencing the ratings of S6. Most children *agreed* that in-game feedback is essential, as they could know that the progress of their gameplay through the scores they have earned or lost. It is very important to provide children with information about their achievement while playing in order to sustain their motivation, especially for older children.

- **Correlations between the Statements**

While the six statements derived from DEG-7-11 v1 were intended to address different aspects of a game design for children aged 7-11 years, they might be interrelated to some extent. Spearman's correlation coefficients were computed.

As shown in Figure 7.7, 14 out of 15 pairwise correlations are statistically significant. It may imply that some statements can be collapsed. Of particular interest are S1 and S5, which is significantly positively correlated with five other statements. These observations are not surprising as they are all related to the information presentation in a game.

Spearman's correlation coefficients (r_s) of the 6 statements (N =182)

	S2	S3	S4	S5	S6
S1	.257**	.247**	.323**	.417**	.373**
S2		.148*	.344**	.196**	.108
S3			.190*	.310**	.378**
S4				.420**	.274**
S5					.428**

** Correlation is significant at $p < 0.01$
* Correlation is significant at $p < 0.05$

Figure 7.7 Pairwise correlations of the six statements

To validate DEG-7-11#3, the favourite character selected by each gender of altogether valid 56 children who played FoodGroups-A was counted and compared (Table 7.20).

Table 7.20 Cross tabulation of favourite character of each gender

Gender	Character		
	Girl chef	Boy chef	Total
girl	26	3	29
boy	1	26	27
Total	27	29	56

The data supports that the different genders tended to select their own favorite character according to their own gender. Girls often selected a girl chef as their own avatar, same as boys often selected a boy chef as their own avatar. It can be inferred that children agreed with DEG-7-11#3: *One single DEG could suit different genders so that children can select or create their own favourite avatar*.

To validate DEG-7-11#7, the children's responses to Statement#4 derived from the GameFlow model was analysed. The two DEGs were compared in terms of animation effects. As the datasets are not normally distributed as indicated by Shapiro-Wilk test ($p < .05$), non-parametric statistical test, Mann-Whitney U test, was used for testing the difference between groups of children who played two different games (two independent samples) (Table 7.21).

Table 7.21 Ratings of the opinion on animation effect (Statement#4)

GAME / Statement	FoodGroups-A			FoodGroups-B			Statistics	
	Mean	N	Std	Mean	N	Std	U	*p*
I liked the animation effects (e.g. speed, timing).	4.26	58	.928	3.00	65	1.046	-6.294	.000**

Table 7.22 Opinions on animation effect (Statement#4) group by children' gender and game experience

	GENDER								GAMES EXPERIENCE							
	girl			boy			Statistics		Low			high			Statistics	
	Mean	N	Std.	Mean	N	Std.	U	*p*	Mean	N	Std.	Mean	N	Std.	U	*p*
FoodGroups-A	4.31	32	.89	4.19	26	.98	-.419	.675	4.29	24	.85	4.24	34	.98	-.009	.993
FoodGroups-B	3.18	39	.88	2.73	26	1.21	-1.318	.188	3.04	23	1.02	2.98	42	1.07	-.174	.862

Table 7.21 shows that mean of the preference on the animation effect of FoodGroups-A were higher than that of FoodGroups-B. There was significant difference in the preference between the two games ($U = -6.294$, $N_A = 58$, $N_B = 65$, $p < .05$).

The data shows that children liked the animation effects of FoodGroups-A than FoodGroups-B. They preferred cartoon-like animation of FoodGroups-A than static cartoon-like of FoodGroups-B. It can be inferred that children agreed with DEG-7-11#7 which specifies that cartoon-like animations can enhance their imagination It can be argued that cartoon-like animations is much familiar and their expressions are more understandable to children as mentioned in the literature review part.

7.2.23 Summary

Generally speaking, the children involved in the study tended to *agree* with the eight statements derived from DEG-7-11 v1. Of particular interest is S1 ("*The instructions should make me understand the main goal of the game*.") with which the children *strongly agreed*. This observation is consistent with the main theoretical frameworks on which the statements were drawn. A goal presented in a clear, concise and attractive manner (especially in the context of a game) can serve as a concrete object which a child aged 7-11 operates (i.e., the Piagetian development view). In the same vein, the goal of a game plays a key role in guiding a child to learn in different instructional conditions and events (i.e., Gagné's learning theory). It can argue that the eight DEG-7-11 v1 heuristics are theoretically well-grounded, exemplifying an approach to which the heuristics development work can reference.

The three demographic variables – age, gender and game experience – did not play any significant role in the children's opinions on the eight statements. However, there were two exceptions: S3 on the importance of relaxation of a DEG, and S6 on the inclusion of in-game feedback in a DEG. Some genders-stereotypic attitudes towards specific game features can be identified. Nonetheless, the findings in the related literature on the relations between games and genders have been rather inconsistent (e.g., Law & Sun, 2012), and such relations are likely to evolve into some new patterns due to the rapid development of game industry as well as game research. Also, age-range should be taken into account for designing proper DEGs. The youngest children and the oldest children (i.e., 7 years old children and 11 years old children in this context) might require different features of DEGs to sustain their motivation.

7.3 Overall Discussions

Although, the results showed that the experiential value of FoodGroups-A was shown to be better than FoodGroups-B considering from the means of the ratings on the dimensions of KidsGEQ of FoodGroups-A were higher than those of FoodGroups-B (Table 7.11), the means are still very close. It might be implied that the game which designed by following all DEG-7-11 v1 heuristic did not produce high contrast preference to the other game that designed by following only two essential heuristics. It might be discussed that the DEG-7-11 v1 heuristic might not be significantly potential

to be applied solely when designing a DEG. DEG-7-11 v1 heuristic is only considered a subset of the GameFlow model. It might not be able to replace the GameFlow model although it was developed to bridge the gaps of the GameFlow. It would be indicated that the GameFlow model is needed mainly when designing a digital game; DEG-7-11 v1 heuristic is needed as a supplementary guideline when designing specifically a DEG for children aged 7-11 years as the DEG-7-11 v1 heuristic created an effect on the design. DEG-7-11 v1 heuristic could be proposed as an augmented set of GameFlow model.

7.4 Observations and Interviews

To enhance the credibility of this research project, *triangulation* techniques for gathering data from multiple sources of data and analysing them with multiple approaches were used (Read. & MacFarlane, 2006). Mixed method approaches including questionnaires, observations and interviews were used. The observation coding scheme (Section 3.7; Appendix A; Appendix B) was applied to consider what verbal or nonverbal behavior children would display while the DEGs test sessions were being run. Hanna, Risden, and Alexander (1997) supported that these behavioural signs are more reliable than asking children how they prefer game as they are eager to please researchers. Unfortunately, due to different constraints, I could not collect enough observational or interview data to be reported.

7.5 Overall Conclusion

The research finding was that designing DEGs with the DEG-7-11 v1 created an experiential and educational effect. The empirical results showed that the game, which was designed by applying all the eight heuristics of DEG-7-11 v1, was perceived more favourably by its target group – children aged 7-11 years - than its counterpart, which was designed by following only a subset of the heuristics (i.e., the two essential ones). Specifically, the between-subject study (two independent groups) indicated that there was statistically significant difference in learning gain in food groups between two groups of children who played one of the two games. The results could verify the effectiveness of DEG-7-11 v1.

Moreover, the participating children agreed with most of the child-friendly statements derived from DEG-7-11 v1.

In addition, the method of producing a child-friendly version of heuristics originally meant for professional users was shown to be a new useful evaluation approach. The child-friendly version of the GameFlow model which were valid, as well as the child-friendly version of DEG-7-11 v1 which was more perceptive for children can contribute to evaluate gameplay experience of DEGs for children aged 7-11.

Chapter 8: Evaluation of Existing DEGs using DEG-7-11 v1

Nowadays, game reviews and game ratings are generally used for judging the popularity of games. The question of which features contribute to high ratings of games was addressed in this study. Fifteen DEGs in a free game website were selected to be analysed by using DEG-7-11 v1. The aim was to evaluate to what extent the designs of the main features of the selected DEGs with high user preference ratings are consistent with the DEG-7-11 v1 heuristics. This evaluation approach is another means to verify the effectiveness of DEG-7-11 v1.

8.1 Background

Currently, DEGs are employed widely as a supporting learning tool in primary schools. How well they can balance educational effectiveness and enjoyment is the key success factor of such games. This chapter describes an instance of using Heuristic Evaluation (HE) to inspect the features of the existing DEGs. Fifteen DEGs have been evaluated with the eight heuristics of DEG-7-11 v1 and the evaluation results were compared with the market ratings of the individual games. This approach can validate the assumption that if a DEG is designed by following the heuristics of DEG-7-11 v1, its success can be assured to a certain extent.

8.2 Research study

The study aimed to empirically evaluating DEG-7-11 v1 by analysing existing DEGs of different domains to evaluate the relationship between market statistics and the number of the DEG-7-11 v1 heuristics each of them followed.

8.2.1 Apparatus

8.2.1.1 Selection of Games

Several computer games were picked from the website named Learn4Good[4]. The web began in 2003; it has received over 25 million visitors a year since 2007, and is consistently among the top 20 thousand websites for overall traffic. It has a global

[4] www.learn4good.com/games

audience and its purpose is to provide a highly professional online service to schools, colleges, universities, students, parents, employers, recruiters, international organizations, jobseekers, and travelers. It contains free web-based games for children in different school levels, ranging from kindergarten, elementary, middle and high schools. It also provides games to play in the classroom or with family at home as reinforcement and practice. It hosts various interactive learning games on different topics, including mathematics, science, physics, engineering, puzzles, hard brain-teasers, and others. Specifically, public ratings and user reviews are available on the webpages of the individual games. The data are very useful for the study of this chapter.

8.2.1.2 The process of selecting the games

The games that were used in this study are "Educational Games". All the selected games, limited to a manageable size of 15 games and to those which have been played and voted by a reasonable number of players, are from the same category in order to minimize biased opinion on the games features. DEGs contain some features beyond entertainment games (Sørensen & Meyer, 2007), especially the features that support learning as reviewed in Chapter 2, Section 2.1. The games all run on PC in order to remain the similar gameplay mechanism such as using a mouse to control characters in games. No specific contents have been targeted. Instead, various contents were randomly chosen in order to prove that game features which support learning do not depend on game contents.

After playing a game, players can rate their preference with a scale (Figure 8.1). Player preference (%) is composed of 3 scales: Love It, Like It, and Not 4 Me. The 15 games chosen for this study was based on "Love It %" and have been played and voted by a reasonable number of players. Each game with different Love It % was selected in order to test how the different value correlate to the percentage of DEG-7-11 v1 heuristics followed by that game. Details of these DEGs are displayed in Table 8.2.

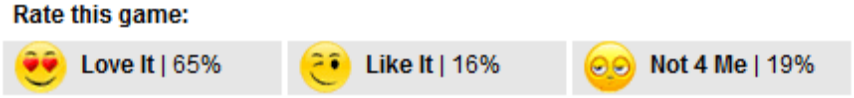


Figure 8.1 Player preference: the rating scale used in the website Learn4Good (see footnote 4)

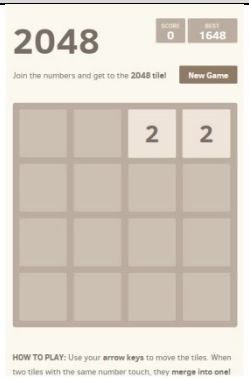
8.2.1.3 Heuristics of DEG-7-11 v1

The eight heuristics of DEG-7-11 v1 (Table 8.1) were applied as usability principles to inspect a selection of 15 DEGs.

Table 8.1 The eight heuristics of DEG-7-11 v1

DEG-7-11#1: Instead of setting a goal on performance, such as scoring, like entertainment games, for a DEG, a specific learning goal should be set. Also, the goal should be clear, concise, simple, and presented early in the DEG.
DEG-7-11#2: Children aged 7-11 should be supported by instructions when playing a DEG; the instruction should explain how to get correct answers, but without relying on text-based manual only.
DEG-7-11#3: One single DEG could suit different genders so that children can select or create their own favourite avatar.
DEG-7-11#4: A DEG for children aged 7-11 years should be relaxing to play by having minimalistic interfaces, appropriate speed, and no time pressure.
DEG-7-11#5: A DEG should be separated into multi-levels with initial levels being disguised tutorials, enabling children to practise new information by performing similar tasks.
DEG-7-11#6: A game should incorporate reminders that children can use for recalling information from their memory.
DEG-7-11#7: Animations can influence learning for children aged 7-11 years, especially cartoon-like animations can enhance imagination and fun, resulting in playful learning.
DEG-7-11#8: Rewards and punishments should be provided in the form of in-game feedback interfaces; they are incentives and can inform children aged 7-11 years about their progress and learning.

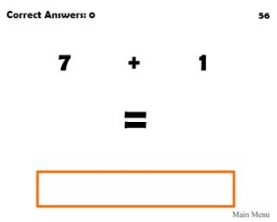
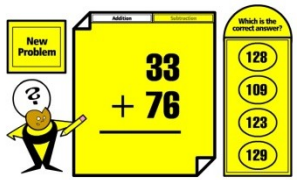
Table 8.2 15 selected DEGs and Player-based evaluation of each game: Player preference (Love It %), and Overall Quality scores (Rating: from 1 to 10) and Number of players voted (Votes), as of 16th July 2015.

Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
1) 2048	84	9.1	17		2048 is a highly stimulating, interactive, sliding-tile brain teaser game where players combine together pairs of identical number tiles in order to continuously double them up – with the overall goal of creating a tile of the number 2048. Although this is a math game at its core (some addition math skills are beneficial), keeping control of the sliding tiles is the key aspect. This requires good analytical thinking and problem solving skills, patience, concentration, determination, good strategy, savvy keyboard or swipe control skills - to visually and mentally figure out and make the optimum next move in line with the goal. There is no time limit, so a careful and measured approach is definitely the way to go here.
2) Axon	81	8.8	157		Axons are real biological nerve fibre present throughout human body. The game assists players in understanding more about the science behind nerves, nerve endings, brain and nervous system. A neuron is any cell within the nervous system, and an axon is part of a neuron (kind of like that legs are part of the human body). Axons are responsible for transmitting messages to neighboring neurons, a process that is essential for physical movement and thought processes. For example, if brain sends a message to hand to click mouse, that message is transmitted to hand by axons! Using mouse or touchpad, click on any of the white Protein Spheres that appear within 'Range

Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
					of Influence' in order to connect the fibers of nerve cell (an action similar to joining up dots). This is a large circular shaded area that decreases slowly as the seconds tick by. Each clicking on a Protein Sphere, axon grows further (higher in the screen). The game ends when circular 'Range of Influence' fully contract. The longer neuron is grown, the more complex the final cell.
3) Amusix Flute	72	8.2	1,077		This is an interactive music-based typing game where players have to type along to the tune of classical flute music as fast as they can. Every key that players hit corresponds to a musical note in the tune that is being played as they practice their typing skills. Play a tune by typing out the letters that appear at the bottom of the game screen. Hold down each corresponding key long enough to play the full note. Once players start playing a note – the letter icon will quickly start to fill up in green color. Once it fills completely, quickly move onto the next letter – and so on until the end of the tune. If their typing is precise, and they get most of the letters correct, they progress to the next tune.

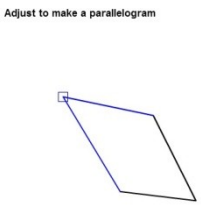
Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
4) 7 Moves	69	8	772		A great tile puzzle game, and involves some basic math (addition and subtraction). The mission as a treasure hunter is to find and collect all treasures in each cave. But players need to make exactly 7 moves (tile steps) in order to reach each treasure chest. Use the arrow keys on computer keyboard to move around from tile to tile. The 7th move must be used to collect the treasure. That means that the 6th move must bring players next to the treasure. Players cannot move back to a tile they have landed on, and there are tiles that cannot be moved or used. As players progress, the levels become more challenging as they have to use some basic addition and subtraction. Here, there are tiles that can provide players with an extra move (8th and so on) or less in order to help them out to make the path to the treasure.
5) Perfect Balance 3	64	8	245		This game requires a basic understanding of science – gravity, mass, geometry and how balance-beams work. Perfect balance is considered when no object is wobbling or sliding. Simply click on a shape located at the top of the screen to pick it up. Left click mouse again if put the object back. Choose the position of the figure, rotate it clockwise or counter clockwise by pressing the A or D keyboard. Once the figure is in place – left click mouse again and the figure will be released. Don't just drop objects, as a falling object may push some other object out of place. If an object falls down or floats up – the level is failed. It makes it harder for players to play a higher level without proper experience.

Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
6) Color Traffic 2	64	7.5	1,034		Color Traffic 2 teaches players to be a good and trustworthy traffic control manager. Players use mouse to control the traffic flow by clicking on the markers and arrows to change the driving direction of the cars, and prevent accidents and traffic jams. Some of the arrows allow players to adjust the speed of the traffic by dragging them forward to increase the speed and dragging backward to decrease the speed. The faster players direct the cars along the correct route, the more points players earn. The coloured cars have different routes to follow depending on the colour of the car. There is a timer located in the top right corner of the game screen. There are lots of routes (levels) to complete. Levels increase in difficulty as players' progress. The next level is unclocked only when the previous one is complete.
7) SoloWords	60	7.5	477		SoloWords is an anagram-type of word game where players need to unscramble letters to create new words, and place them horizontally on the board. The game consists of 4 rounds where players must score points to achieve a total score. Players can choose the letters from the bottom on tiles. To form a word, click on the letter tiles one by one. If selecting an incorrect letter, and want to place it back on the rack, just click on it again. A round is over after players have placed words on all 5 rows or after time runs out. Players can click buttons to the right of the rack to shuffle or get different letters. Words created can be shorter than the rows provided. If placing a full length word in a certain row, players earn the bonus points that are shown on the row.

Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
8) Maths Workout 2	58	7.1	995		Players' aim is to answer as many mathematical problems correctly as they can. However, all the problems have to be answered in 60 seconds! Players choose the level of difficulty (easy, normal, hard) or the type of math to practice (addition, subtraction, multiplication, division). Simple guidelines about how visualize the problem and how to use shortcut for calculating are provided to encourage players to achieve great results. When answering a math question, enter the number and press the 'Enter' key on keyboard to submit it. Players will receive a new math question straight afterward. A red X indicates that the answer is incorrect, and players have to think again. The game is over when time runs out. When playing the 'hard' level, players lose points with every incorrect answer. Try to beat other highscores and to get in the leader boards.
9) Double Digits	51	6.5	7851		Children could learn Math subtraction and addition by practicing lots in the fun and challenging educational game. Players calculate the Math problem displayed on the game screen. Then they click on the correct answer on the right side of the game screen.
10) Word Mountain	51	6.8	784		Word Mountain is a fast-paced and innovative typing game where players compete against an opponent to reach the top of a mountain by typing words as quickly as possible! This game should also help improve spelling as players can only jump up the mountain if they spell the word on the screen correctly. At the beginning of each level, players start at the bottom of a mountain as a cute bird character, climbing up and up every time players correctly type in a

Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
					word. There are four difficulty levels – Easy, Medium, Hard and Crazy. As players progress through the levels, the words that they have to type become longer and more complicated. Players only have a certain number of seconds to type in the word and the amount of seconds depends on the difficulty level.
11) USA 50 States	50	6.3	292		USA 50 States is a picture puzzle. This game could be a good activity for learning about the state geography of the US, the various state borders, shapes and sizes. It could also be used to help to exercise / improve memory skills and cognitive ability (If a child places a state in an incorrect position on his/her first attempt, he/she can strive to remember its position in future plays)! Players have to click and drag each of the 50 individual states into its correct position on the map of the United States, and to minimize the amount (and scale) of positioning errors. Beginning with a totally empty map, players have to slowly fill in the vast area, state-by-state, until the map is complete! At the end of the game, players are shown their Perfect Score percentage, Average Error, and the amount of time it took to complete the puzzle.

Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
12) Race Across the Steppe of Mongolia	40	4.9	132		Race Across the Steppe of Mongolia is an interactive educational quiz game where players have to answer questions about facts (history and customs) of Mongolia – a land-locked country in Asia between China and Russia. Mongolians love everything equestrian, especially horse-racing – and the questions in the game reflect this. Each time players correctly answer a question, Togi's horse moves ahead in the race. Answer enough questions correctly to ensure Togi wins the race – bringing pride to his family, and his community of nomadic herders. There are 10 questions in total, and players must answer at least 5 correctly to win the race for Togi. Players are told instantly if they got it right or wrong. If Togi loses the race, players can try again.
13) Are You My Blood Type?	33	4.7	476		The slickest part about this online game is to learn which blood types match and which don't. The story – Some people have just been rushed to the hospital emergency department from a major car accident. They are rapidly losing blood and urgently need blood transfusions before the operations are completed. Match the blood type of recipient (bottom of the game screen) with the blood type of one of the donor's (top of the game screen) and save their lives. The more pairs matching, the more points getting. The game has a time limit, and with each new round, the time gets shorter.

Game Name	Love It (%)	Rating (10)	Votes	Screenshot of the landing page	Description
14) Space Words Defense	33	4.6	337		Space Words Defense is a fun interactive typing game where players get to save the galaxy while practicing typing skills at the same time! Mission is to blast (type) through 6 different levels in order to save the planet from the nasty aliens (Kloguns)! Once the alien ships approach, type the word on top of them. The lasers will then be aimed at the aliens and will blast them out of the skies! The faster players type, the higher players score. Once the ship (word) leaves the game screen (without being blasted), players lose a life. Remember to be careful. These words can get big and nasty! No spelling mistakes! If players make too many mistakes, they won't pass the level and all of earth will suffer.
15) Eyeballing	27	4.1	248		Eyeballing is a challenging geometry math game that requires super-sharp eyesight and a solid appreciation of space and distance. Players have to follow the instructions at the top of the game screen. Players might be asked to find the midpoint of a line segment, the point of convergence of three lines or to bisect an angle. Use computer mouse to click and drag the blue line (or square target) to the correct point in the game screen. Players need to achieve accuracy to zero units.

8.2.2 Method

I aimed to validate DEG-7-11 v1 by estimating the extent to which the designs of existing DEGs for children aged 7 -11 are consistent with the DEG-7-11 v1 heuristics. The research assumption is as follows:

The higher the number of the DEG-7-11 v1 heuristics followed by a DEG, the higher the quality of the DEG is, leading to a higher average player preference rating.

To verify this assumption, the percentage of 'Love It' of a game would then be correlated with the percentage of DEG-7-11 v1 heuristics followed by that game as described in the next sections.

8.2.3 Procedure

A typical *Heuristic Evaluation* proposed by Nielsen (2001) has been conducted. I, as an evaluator, used usability principles, named DEG-7-11 v1 heuristics, for inspecting the interfaces, which are the 15 selected games.

Nielsen (2001) stated that in terms of how to proceed with evaluating the interface, the evaluators can decide on their own, however going through the interface at least twice is recommended. Getting the flow and the general scope of the system would be the first pass and focusing on specific interface elements would be the second pass. Accordingly, I have gone through the games interface with two rounds. First, I browsed a game in the first round to know its main goal and its mechanics and to see which features it has. Then I played the game in much more detail, checking each game feature to see if it follows or violates any of DEG-7-11 v1 heuristics. If a particular heuristic is followed by the game, 'Y' (Yes) is assigned; otherwise, 'N' (No) is assigned. For example, the game named "Axon" is a fast-paced gameplay. The game requires children to have fast reflexes, and accurate mouse-clicking on a Protein Sphere which decreases in size in every second. Its feature violates DEG-7-11#4 (speed and time limit); it is not relaxing to play. Contrast with the game named "2048" which has no speed or time limit, children can use their unlimited-time and effort to slide the tiles to combine pairs of identical number tiles to create a tile of the number 2048. As this feature does not violate DEG-7-11#4, then 'Y' is assigned to "2048" and 'N' is assigned to "Axon" (Table 8.3). The same procedure has been applied to inspect other features of the 15

selected games by using each of the eight DEG-7-11 v1 heuristics.

Percentage of DEG-7-11 v1 heuristic followed of each game was calculated as shown in Table 8.4. Then, they were compared with the user preference statistics (Love It %) obtained from the website (Table 8.5).

Table 8.3 The example of using DEG-7-11#4 heuristics to inspect a feature of relaxation in the two different games

Game Name	**DEG-7-11 v1 heuristics #**							
	1	**2**	**3**	**4** **"..relaxing to play.."**	**5**	**6**	**7**	**8**
1) 2048				Y No speed or time limit				
2) Axon				N Fast-paced and time limit				

Table 8.4 Percentage of DEG-7-11 v1 heuristics followed by each of the 15 selected games, as indicated in the column "Followed (%)". The column of DEG-7-11#3 is highlighted to show the unique finding.

Game Name	**DEG-7-11 v1 heuristics #**								**Followed (%)**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
1) 2048	Y	Y	N	Y	Y	Y	Y	Y	**87.5**
2) Axon	Y	Y	N	N	N	N	Y	Y	**50**
3) Amusix Flute	Y	Y	N	N	Y	Y	Y	Y	**75**
4) 7 Moves	Y	Y	N	Y	Y	N	Y	Y	**75**
5) Perfect Balance 3	Y	Y	N	Y	Y	Y	Y	Y	**87.5**
6) Color Traffic 2	N	Y	N	N	Y	Y	Y	Y	**62.5**
7) SoloWords	Y	Y	N	N	N	Y	N	Y	**50**
8) Maths Workout 2	Y	Y	N	N	N	N	N	Y	**37.5**

Game Name	DEG-7-11 v1 heuristics #								Followed (%)
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
9) Double Digits	Y	N	N	Y	N	N	N	Y	**37.5**
10) Word Mountain	Y	N	N	N	Y	N	Y	Y	**50**
11) USA 50 States	Y	Y	N	Y	N	Y	N	Y	**62.5**
12) Race Across the Steppe of Mongolia	Y	Y	N	Y	N	N	Y	N	**50**
13) Are You My Blood Type?	Y	Y	N	N	N	N	N	Y	**37.5**
14) Space Words Defense	N	N	N	N	Y	N	N	Y	**25**
15) Eyeballing	N	N	N	Y	N	N	N	Y	**25**
No. of games followed that heuristics	**12**	**11**	**0**	**7**	**7**	**6**	**8**	**14**	
%	**80**	**73**	**0**	**47**	**47**	**40**	**53**	**93**	

Table 8.5 Comparison of the percentage of DEG-7-11 v1 heuristics followed (Followed) and the user preference statistic (Love It) of each game

Game Name	Followed (%)	Love It (%)
1) 2048	87.5	84
2) Axon	50	81
3) Amusix Flute	75	72
4) 7 Moves	75	69
5) Perfect Balance 3	87.5	64
6) Color Traffic 2	62.5	64
7) SoloWords	50	60
8) Maths Workout 2	37.5	58
9) Double Digits	37.5	51
10) Word Mountain	50	51
11) USA 50 States	62.5	50

Game Name	Followed (%)	Love It (%)
12) Race Across the Steppe of Mongolia	50	40
13) Are You My Blood Type?	37.5	33
14) Space Words Defense	25	33
15) Eyeballing	25	27

8.2.4 Results and Discussions

The results of Heuristic Evaluation are summarized in Table 8.4. On average, 54% (SD = 20.4, Range: 25% - 87.5%) of the DEG-7-11 heuristics have been followed by the 15 selected games.

The research assumption stated previously implies a significant positive correlation between player preference ratings (measured by the variable 'Love It' %) and percentage of the DEG-7-11 v1 heuristics followed by a game (measured by the variable "Followed %"). To verify this assumption, we have computed the Pearson correlation coefficient between the two variables. The parametric test has been used, given that the datasets are normally distributed as indicated by the output of Shapiro-Wilk tests ($p > .05$).

The result shows that there is a highly significant correlation between Player Preference ratings and percentages of DEG-7-11 v1 heuristics followed ($N = 15$, $r = .753$, $p < .01$). It implies that the higher the number of DEG-7-11 v1 heuristics is followed when designing a DEG, it is more likely that the DEG will have a higher user preference rating.

When computing for each heuristics, 80%, 73%, and 93% of 15 games followed DEG-7-11#1, #2, and #8 respectively. Most DEGs provide "a learning goal", "instructive and multimodal instruction", and "reward and punishment feedback" for their players. As mentioned in literature review, a learning goal is the source of motivation that inspires children to use their effort to play the game. The instructive and multimodal instruction enables children to explore the games themselves. Also, reward and punishment feedback is one of the critical game elements that sustain the player's motivation to play the game. Especially, I have categorized DEG-7-11#1 and DEG-7-

11#2 as *essential heuristics* in the sense that they must be followed so that a game can be qualified as a DEG. The result of the analytic evaluation can demonstrate that these two heuristics are needed for a DEG designing; without applying them a game will probably have lower user preference rating.

In addition, it is found that approximately 47%, 47%, 40%, and 53% of the games followed the DEG-7-11 v1 heuristics #4, #5, #6, and #7, respectively. It can be inferred that the game designers might take into account the psychological frameworks, including emotion (Rolls, 2005; Russoniello, O'Brien, & Parks, 2009), memory (Baddeley, 1997), cued recall (Moult, 2011) and design guidelines such as animation (Scaife & Rogers, 2005) when creating their DEGs. The games following the heuristics #4, #5, #6 and #7 are multi-levels with initial levels serving as disguised tutorials. The games also incorporate in-game hints to support children's gameplay. The games aim to enhance fun by including cartoon-like animations. Moreover, the games are designed to be relaxing to play. These results tend to support the assumption that if a DEG is designed by following the *recommendable heuristics*, the game can get higher player preference.

Interestingly, none of the selected 15 games followed DEG-7-11#3 (*One single DEG could suit different genders so that children can select or create their own favourite avatar*). Here I discuss some issues pertaining to *gender-based adaptation*. According to Boyle and Connolly (2009), although some guidelines in developing DEGs specify that new learning materials should aim to be gender neutral, traditional computer games are still developed to be more appealing to males than females. A plausible explanation is that developing DEGs that are appealing to both genders requires additional level of complexity and thus additional resources in terms of time and effort. Ideally, DEGs should be adaptive or personalized based on player gender, which is known to be critical factors influencing the motivation to play (Sun & Law, 2010). For the future work, the reasons underlying the non-compliance with this gender-based heuristic and appropriate remedies for improving the situation should further be investigated.

It can be encouraged that if the individual 15 games were designed to support gender-based adaptation framework (Section (i)), user preference ratings of the individual games might higher, as the above result supports that *the higher the number of heuristics of DEG-7-11 v1 are followed, it is more likely that the DEG will have a higher user preference rating*.

Overall, this analytic evaluation study has validated the assumption that DEGs, when following the DEG-7-11 v1 heuristics, are likely to be accepted and enjoyed by their users. However, based only on the player preference ratings, it is not possible to validate if the 15 games evaluated are educationally effective. Results of the empirical user-based evaluation with the two game prototypes (Chapter 7) would shed light on this issue.

8.3 Discussions

Although the study revealed that the proposed set of heuristics addresses quite well the features that need to be taken into account when designing DEGs, some confusion while conducting the heuristics evaluations were found. The evaluator should consider which heuristics are relevant for the game, but it is found that a few heuristics could not address suitably some game features. For example, a game already provides instructions when playing, but the instructions of the game do not explain how to get correct answers. The example shows that there are two features needed to be considered by DEG-7-11#2. When conducting heuristic evaluation, the evaluator might be confused to decide to put Y or N as it meets only half of DEG-7-11#2. So, the clarification of the DEG-7-11#2 together with guidelines to use is needed.

8.3.1 DEG-7-11 v2

The discussion leads nicely into a consideration and the design of the second version of DEG-7-11. This section describes how the DEG-7-11 v1 is being morphed into DEG-7-11 v2. A set of new heuristics, DEG-7-11 v2, together with a set of guidelines for how they can be used is presented in Table 8.6.

Table 8.6 The eight heuristics of DEG-7-11 v2

DEG-7-11 v1	DEG-7-11 v2	Guidelines to use
DEG-7-11#1: Instead of setting a goal on performance, such as scoring, like entertainment	**DEG-7-11#1:** For a DEG, a specific learning goal should be set instead of a goal on performance like scoring.	- A learning goal needed to be provided to offer children prepare themselves to play and learn. - The goal should be presented

DEG-7-11 v1	DEG-7-11 v2	Guidelines to use
games, for a DEG, a specific learning goal should be set. Also, the goal should be clear, concise, simple, and presented early in the DEG.	Also, the goal should be clear, concise, simple, and presented early in the DEG.	before the game is started; however, an instant learning goal is accepted. - The goal should be clear, concise, and simple in order to reduce the risk of instructions being ignored. - Scoring is just a kind of feedback to inform the progress while playing but not a goal to complete the game.
DEG-7-11#2: Children aged 7-11 should be supported by instructions when playing a DEG; the instruction should explain how to get correct answers, but without relying on text-based manual only.	**DEG-7-11#2:** Children aged 7-11 should be supported by instructive instructions when playing a DEG; they should explain how to get correct answers, and without relying on text-based manual only.	- It's not enough to have just instruction of how to play a game, how to get the right answer and the example of the right answer should be specified along - Only instructions which are not instructive are not accepted. - Any types of instructive instruction such as explanations, modelling, worked examples, or walkthrough, should be included helpfully. - Short text-based instructive instructions with learning goal might be accepted together with multimodal formats such as short video clips, animations. - Only text-based instructive instructions are not accepted.
DEG-7-11#3: One single DEG could suit different genders so that children can select or create their own	**DEG-7-11#3:** One single DEG could suit different genders so that children can select or create their own	- Different avatar should be options for children to select their own favourite. - Opportunity to create their

DEG-7-11 v1	DEG-7-11 v2	Guidelines to use
favourite avatar.	favourite avatar.	favourite avatar might be given.
DEG-7-11#4: A DEG for children aged 7-11 years should be relaxing to play by having minimalistic interfaces, appropriate speed, and no time pressure.	**DEG-7-11#4:** A DEG for children aged 7-11 years should be relaxing to play, such as having minimalistic interfaces, appropriate speed, and no time pressure.	- Any feature which can promote relaxation should be created such as having minimalistic interfaces, appropriate speed, and no time pressure.
DEG-7-11#5: A DEG should be separated into multi-levels with initial levels being disguised tutorials, enabling children to practise new information by performing similar tasks.	**DEG-7-11#5:** A DEG should provide disguised tutorials in initial levels, or should have multi-challenges in a level, enabling children to practise new information by performing similar tasks.	- A DEG should be separated into multi-levels with lower levels giving basic knowledge for playing its higher levels. - A game with no level, but it is multi-challenges, such as gradually harder with different information or tasks in a level, should be accepted.
DEG-7-11#6: A game should incorporate reminders that children can use for recalling information from their memory.	**DEG-7-11#6:** Strategies to recall information from children's memory, such as reminders, should be incorporated.	- Any kinds of reminders or hints should be incorporated.
DEG-7-11#7: Animations can influence learning for children aged 7-11 years, especially cartoon-like animations can enhance imagination and fun, resulting in playful learning.	**DEG-7-11#7:** To create playful learning, things that enhance imagination and fun should be used such as animations, especially cartoon-like animations.	- There should have cartoon-like animations rather than human-like characters. - Exaggerated expressions and behaviors of cartoon-like characters should be utilised rather than realistic expressions of human-like ones.
DEG-7-11#8: Rewards and punishments should be provided in the form of in-game feedback interfaces;	**DEG-7-11#8:** To create deep learning which evoked by emotions, motivation like rewards can help. Rewards	- There are various ways of offering motivation like rewards such as scores.

DEG-7-11 v1	DEG-7-11 v2	Guidelines to use
they are incentives and can inform children aged 7-11 years about their progress and learning.	should be provided in the form of in-game feedback interfaces; they can also inform children about their progress.	- Any other in-game feedback to inform children's progress and learning could be provided, for instance, sound effects.

8.3.2 The importance of the different DEG-7-11 v1 heuristics

It was found that all the DEG-7-11 v1 heuristics were not equal important. Table 8.4 shows that most of games (93% of games) followed DEG-7-11#8. It might be implied that the most important feature that should be included in a DEG is rewards in the form of in-game feedback. As some researchers suggest that reward and punishment is the one of the critical game elements that lead to positive emotions and sustain the player's motivation to engage in the game (Rolls, 2005; Sweetser & Wyeth, 2005; Wang & Sun, 2011). While, none of the games (0% of games) followed DEG-7-11#3, it might be assumed that the feature of providing different avatars for different genders is the least important. A DEG could be designed not aim to be gender neutral, as long as its design can appeal specific gender target group. However, the assumption argues the importance of gender-based adaptation proposed by previous researchers such as Boyle & Connolly (2009) and Sun & Law (2010).

However, the assumptions would not be the judgment to rank the importance of the different DEG-7-11 v1 heuristic. Because the heuristic evaluation was applied to inspect the interface of DEGs; it is not possible to validate the educationally effective of the games. Thus, the importance ranking of each heuristic is not proposed in this research study. Future studies might be needed to prove the above assumptions to be reliable both usability and educationally effective of the games until they can be the good judgment for importance ranking of the heuristics. The finding might lead to a new version set of DEG-7-11 or DEG-7-11 v3.

8.4 Conclusion & Outlook

With the increasing use of unconventional educational interventions (cf. chalk-and-talk in classroom) for young children, DEGs are promising tools being developed to promote learning outcome and enjoyment simultaneously. Game designers or UX professionals in the field of Human Computer Interaction need to have guidelines for developing games to ensure quality user experience as well as better learning outcomes. This Heuristic Evaluation study reported in this chapter has lent support to the assumption that if game designers disregard some important features, the games might have some deficiency as identified in the above analysis, leading to its low player preference ratings. In addition, the results infer that DEG-7-11 v1 can be effective guidelines for designers to create a successful DEG. Finally, the wording of some of the DEG-7-11 v1 heuristics was modified to improve their understandability, resulting in DEG-7-11 v2. Thus, DEG-7-11 v2 is another contribution from this chapter.

Chapter 9: General Conclusion

Each of the previous chapters of this thesis addressed some specific research questions (RQs). In this final and concluding chapter, I present a summary how each of the RQs was answered based on the data gathered.

9.1 Overview

The main aim of my PhD research project was to tackle the challenge of designing and developing games that are simultaneously enjoyable and educationally effective for children aged 7-11. The methodology of the research was divided into five studies with five research objectives and five research questions. Each of the five studies with the related research objective (RO) and research question (RQ) is summarised in Section 9.2 – 9.6, respectively. Each of the sections is structured as follows: Summary and limitations.

9.2 Pilot Study

9.2.1 Summary

RO1: To identify which game features are powerful for motivating children aged 7-11 years to play and for enabling them to learn.

RQ1: Which game features are powerful for motivating children aged 7-11 years to play and for enabling them to learn?

Before designing a DEG that is simultaneously entertaining and educationally effective, it is necessary to know which game features are powerful for motivating children to play and learn. To identify such game features, *playability heuristics* (PH) are adopted and adapted as an *empirical* tool to elicit user requirements.

Theories on PH and the related work were reviewed in Chapter 4. It was found that several sets of PH have been developed by different researchers. Those PH are conventionally used for identifying usability problems of gameplay. The *GameFlow model*, PH of Sweetser and Wyeth (2005), was adopted to be an analytical tool for this study because it is a consolidated set from different PH developed by some other research groups.

The methodology to identify game features was presented in Chapter 3. The GameFlow model criteria were translated into a set of understandable statements for children; the statements were then compiled into an online questionnaire. Children aged 7 to 11 years were asked to use the questionnaire to identify most as well as less preferable features of the existing four games.

The findings in Chapter 4 showed that apart from the traditional use, PH could be used for understanding and eliciting important features of gameplay which are useful for interaction design of DEGs. Some powerful game features for motivating children aged 7-11 years to play and for enabling them to learn were extracted. Importantly, some gaps of existing PH were found and needed to be bridged, and then the need for a specific set of heuristics for designing DEGs for this specific age-group was identified.

9.2.2 Limitations

The capacity of youngest children (i.e. 7 years old children) to understand the statements of the questionnaire and their limited attention span hindered them from going through the whole process of the empirical studies. Thus, there were a number of missing data. The relative lack of input from the younger children is that the analyzing requirement on the features of DEGs might be satisfied to older children than younger one as there were not many numbers of requirements from the younger children to be analysed.

The choices of games used in the Pilot Study are limited to only 4 DEGs as the time limit of the empirical study. Also, the domain of the selected game is limited to foods and nutrition. The preferable as well as less preferable game features extracted from a small number of games and limited domain-specific content might not be diverse enough for deriving an offset of heuristics with a broad coverage for designing the new DEG when they were adapted and synthesized together.

The process of adapting GameFlow heuristics for children included translating the heuristics into understandable statements for children, and the validity of the instrument should be carefully evaluated by some experts in the field of HCI before presenting them to children. An immature measurement instrument can lead to inappropriate results, which might not be reliable enough to inform the development of a set of new heuristics. Nonetheless, using the converted statements was not the sole means for deriving DEG-7-11. Other sources of data such as the children's gameplay behaviours were used for validating the new heuristics.

9.3 Developing Design Heuristics

9.3.1 Summary

RO2: To develop a set of validated design heuristics for DEGs for children aged 7-11 years.

RQ2: What are design heuristics for DEGs for children aged 7-11 years?

The empirical findings of the Pilot Study with children aged 7-11 years for identifying the preferable and less preferable game features of DEGs (Chapter 4) implied a need for a specific set of heuristics for designing DEGs for this specific age-group. This need was aimed to meet by developing a set of design heuristics.

The preferable and less preferable features of DEGs as perceived by school children aged 7 to 11 years from the Pilot Study, three theoretical interdisciplinary knowledge (psychology, pedagogy, and design), and the gaps of the GameFlow model were analysed and synthesized, leading to the derivation of a new set of design heuristics called DEG-7-11 v1. It was a first version set of the eight heuristics for designing DEGs for school children aged 7 to 11 years to enable them to learn a topic effectively and with fun. The methodology for developing the design heuristics was presented in Chapter 3.

DEG-7-11 v1 represents preferable features of general DEGs for primary school children aged 7 to 11 years. The descriptions of the first version of the design heuristics were elaborated in Chapter 5. It can be argued that the eight DEG-7-11 v1 heuristics are theoretically well-grounded, exemplifying an approach to which the heuristics development work can reference.

9.3.2 Limitations

Social aspects have been found to be a powerful trigger to intrinsically motivate people. Also, the GameFlow model (Sweetser & Wyeth, 2005) suggests that games should support and create opportunities for social interaction. However, this research project aims to tackle the challenge of designing and developing a single-player game which children can play individually in a classroom, or play with a teacher or their parents at home. Features of a social or multiplayer game are different to features of a single-player game. A social game can be an online game that is played through social networks, and

typically is an online multiplayer game, which is increasingly popular. However, a social game as such is beyond the scope of this research project, as it entails different sets of heuristics (e.g., Korhonen & Koivisto, 2007; Pinelle, Wong, Stach, & Gutwin, 2009). The group of researchers have developed two different sets of heuristics, one for single player games and one for multiplayer games. Hence, I decided not to include social aspects in DEG-7-11 v1 heuristics. Therefore, the heuristics of DEG-7-11 v1 are broadly applicable to games that children aged 7-11 normally play, except social games. For the future work, DEG-7-11 will be expanded to take social games into consideration.

Because of the limit choices of games used in the Pilot Study (Chapter 4), the preferable as well as less preferable features might be extracted unreliably because of their closeness of the means. The DEG-7-11 v1 heuristics derived from those features might still contain some gaps resulting in the DEGs design issues. This is maybe the first 'sign' to imply that DEG-7-11 v1 heuristics could not replace the GameFlow model even it also contains some gaps. DEG-7-11 v1 heuristics might be an 'add on' to the GameFlow criteria. The progressive version of DEG-7-11 heuristics should be derived in the future.

9.4 Game Design

9.4.1 Summary

RO3: To design and develop new DEGs by integrating and augmenting the preferable features identified and by following the design heuristics (DEG-7-11 v1).

RQ3: How can the design heuristics of DEG-7-11 v1 be translated into the actual game design?

The goal of this study aimed to develop two new games by synthesizing the preferable and less preferable features extracted from the Pilot Study (Chapter 4), and applying DEG-7-11 v1 (Chapter 5) to guide the design of the two games. Although the two games have the same goal of educating children on the knowledge of food groups, they are different in features. FoodGroups-A consisting of 3 sub-games was designed by implementing the preferable features extracted from the results of the Pilot Study and following all the eight heuristics of DEG-7-11 v1, whereas FoodGroups-B having no

sub-game was designed by implementing the less preferable features extracted from the results of the Pilot Study and following only two essential heuristics of DEG-7-11 v1.

The two games can be classified under the genre of casual games. They are easy and relaxing to play, have simple controls, can be completed in 20 minutes. They are 2D, single-user game running on Windows OS. In terms of technical development, the two games into which online questionnaires are integrated were developed by using Adobe Flash, its interactive functions and the questionnaire form were created by Action Script, and the questionnaire databases were connected by PHP.

The pilot test was conducted to evaluate the general usability of the games. Some redesign was taken in order to maximize the preference of the target children.

Chapter 6 describes the implementation of the DEG-7-11 v1 for the game design.

9.4.2 Limitations

Basically, it is very challenging to create one game that meets different needs and goals of children in this age bracket (i.e. one size does not fit all). For the future work, adaptability will be more taken into account for designing a game. The different aspects of children such as age, gender, and game experience will be more concerned to design the game. The game will be more adaptable to those children who are different in the aspects. The game will allow for an appropriate level of customization. Children will be able to identify game elements such as avatars, enemies, obstacles by themselves. The customizable objects can arouse children's interest. The game can be more interactive, challenging and exciting.

9.5 Main Study: Validation of DEG-7-11 v1

9.5.1 Method 1: Validation of DEG-7-11 v1 by Evaluating Two Game Prototypes

9.5.1.1 Summary

RO4.1: To provide a set of validated heuristics for designing DEGs for children aged 7-11 years by comparing the educational and experiential values of the two DEGs developed based on different design heuristics.

RQ4.1: Are there any significant differences in knowledge and gameplay experience, on food groups between two groups of children aged 7-11 years who played one of the two games independently?

Chapter 7 reports three methods conducted to compare and contrast educational and experiential values of the two games. Pre-Test, Post-Test and "Make a Meal" test were used to validate the educational value of the games. After playing the game, children were asked to complete two *gameplay experience questionnaire*s: 1) Gameplay experience measured by KidsGEQ 2) Gameplay experience measured by the child-friendly statements derived from the GameFlow model. If both gameplay experience questionnaires provided results converge, some stronger conclusions about the gameplay experience of the two games could be inferred.

Altogether 182 children aged 7-11 years – the target group of the games - were involved. They were randomly assigned to two groups and tested either FoodGroups-A or FoodGroups-B individually.

9.5.1.2 Method 1A: Validation of the educational value of the games

The knowledge tests (Pre-Test and Post-Test) and "Make a Meal" test were designed to compare the educational value of the games. This study aimed to find out whether and to what extent the game which was designed by following all the eight DEG-7-11 v1 heuristics could contribute to the learning of food groups by children aged 7-11 years.

The result implies that FoodGroups-A, which was designed by following all the heuristics of DEG-7-11 v1 can enhance the development of the children's learning of this specific topic more than FoodGroups-B. However, FoodGroups-B, which was designed by following only two essential heuristics, can also support the learning, albeit to a lower extent than FoodGroups-A.

9.5.1.3 Method 1B-Measure1: Gameplay experience measured by KidsGEQ

The statements of KidsGEQ used to measure games experience of the two games. The hypothesis is that game experience of the game designed by fully following the DEG-7-11 v1 heuristics would be perceived more favourably than the other game designed by partially following the heuristics

FoodGroups-A is more preferable for the sample of primary school children involved. Although FoodGroups-A was slightly more challenging than FoodGroups-B, the children who played FoodGroups-A felt that it could induce significantly higher flow, immersive feeling, competent and positive affect than their counterparts who played FoodGroups-B. Also, the children playing FoodGroups-B felt tenser and had negative affect.

9.5.1.4 Method 1B-Measure2: Gameplay experience measured by the child-friendly statements converted from the GameFlow model

As the games were designed based on the DEG-7-11 v1 heuristics which were derived from the GameFlow Model, to validate the effectiveness of DEG-7-11 v1 the games should be evaluated with reference back to the GameFlow model.

After playing the games, the children indicated what they thought about the games by rating each of the 16 child-friendly statements translated from the criteria of the GameFlow model.

The children who played FoodGroups-A felt more significantly *concentrated*, *challenged*, and *immersed* than their counterparts who played FoodGroups-B. Also, the children playing FoodGroups-A showed a higher preference for the *feedback* provided than those playing FoodGroups-B did, but they did not differ in terms of preference for *clear goals*, *player skills*, and *control* provided by the respective games.

9.5.1.5 The correlation between the two measures of gameplay experience

The relationship between the two measures used to evaluate gameplay experience was investigated. It could be more convincing if the evaluation results of the two gameplay experience were in the same direction.

The result shows that there was a significant correlation between the ratings for KidsGEQ and those for the child-friendly statements derived from the GameFlow model, allowing a solid conclusion about the positive gameplay experience that the children gained through the games.

9.5.1.6 Summary

Overall, results of the study could show how specific game features as informed by DEG-7-11 v1 would benefit the children. The game developed with DEG-7-11 v1 resulted in more effective and enjoyable learning and could produce more satisfaction in the participating children than one using more or less the opposite of DEG-7-11 v1. FoodGroups-A could induce in the children more positive gameplay experience and better learning outcome than FoodGroups-B could.

Based on the empirical findings of the validation study, it can be concluded that the first version set of the eight heuristics of DEG-7-11 have successfully been validated in the current context.

9.5.1.7 Limitations

Nevertheless, it could be aware that a series of full-fledged validation study with a larger number of children, in different domains other than food groups (e.g., computer programming), in settings with different sociocultural backgrounds, and even in more specific age-ranges could provide even stronger evidence to the power and generalizability of DEG-7-11 v1.

Basically, to design a domain-specific DEG, the particularities of the educational domain have to be taken into account. For instance, what holds true for a nutrition game is not necessarily true for, e.g. a code game. Chapter 8 shows the result of applying DEG-7-11 v1 to evaluate 15 DEGs in various domains. Not only for a nutrition game, the evidence supports that the heuristics are applicable in various domains, such as for math games, science games.

9.5.2 Method 2: Validation of DEG-7-11 v1 by Children Rating

9.5.2.1 Summary

RO4.2: To provide a set of validated heuristics for designing DEGs for children aged 7-11 years by translating the heuristics in the form of child-friendly statements for a questionnaire, which was conducted with children of this specific age range.

RQ4.2: To what extent do children aged 7-11 years agree with each of the eight statements derived from DEG-7-11 v1?

Apart from the validation study of DEG-7-11 v1 by evaluating two game prototypes, a validation study where children's agreements on the statements derived from DEG-7-11 v1 heuristics was conducted with children aged 7-11 years. DEG-7-11 v1 heuristics were converted into a set of simple statements, then administered to children aged 7-11 years, who were asked to rate their agreement on each statement. It was assumed that if the children agreed on the child-friendly statements derived from DEG-7-11 v1, the heuristics would be viable for designing DEGs that are useful and enjoyable for the children (Chapter 7).

The findings of the validation study showed that children involved in the study tended to *agree* on the eight statements, especially they *strongly agreed* on DEG-7-11#1. This finding was consistent with my approach of categorizing DEG-7-11#1 as an *essential heuristic* in the sense that they must be followed so that a game can be qualified as a DEG. The results of the validation study show that children also agreed on the other heuristics.

The demographic variables – age, gender and game experience – did not play any significant role in the children's opinions on the eight statements, except DEG-7-11#4 where boys as compared with girls had a higher tendency to strongly agree that a DEG should be relaxing to play, and where DEG-7-11#8: the older the children, the more they tended to prefer in-game feedback.

Given the findings of the validation study, it can be argued that the DEG-7-11 v1 heuristics were empirically and analytically grounded as shown in Chapter 7.

9.5.2.2 Limitations

The validity of the measurement instruments used in the validation study might be disputable. The capacity of children to understand the meaning of statements was questioned. They might be interpreted or understood in different ways, as they could be too general or abstract for children aged 7-11 years.

Although the comprehensibility of the questionnaire was pilot tested with four children and the statements were modified to ensure that the language is child-friendly, there remained some concerns about using the statements to assess with

children having different language skills. Some reviewers commented that as some of the statements were rather general in meaning, children might interpret or understand the questions in many different ways. For example, “I like short and easy games”, this requires children to abstract what is short/easy in comparison to something, as well as it is a double question “short and easy”, what if they like short hard games, the statement asks about two concepts. The statements might not be phrased appropriately. Also some statements are positively worded such as “I am happy…”, it would probably bias the results.

Translating the DEG-7-11 v1 heuristics into statements by myself might cause the issues identified. First, English is my second language. Second, my experience in child psychology and questionnaire design was still limited by then. The statements should have been more thoroughly checked before they were tested with children.

Nonetheless, this evaluation process of asking children to rate the statements played a less important role than evaluating the two game prototypes built upon the DEG-7-11 v1 heuristics – the Method 1 described in Chapter 7.

9.6 Evaluation of Existing DEGs using DEG-7-11 v1

9.6.1 Summary

RO4.3: To provide a set of validated heuristics for designing DEGs for children aged 7-11 years by using DEG-7-11 v1 to evaluate DEGs for various domains.

RQ4.3: Is there any significant relationship between children’s preference ratings and the extent to which the DEG-7-11 v1 heuristics is followed?

It is aware that a full-fledged validation study could provide more and even stronger evidence to the power of DEG-7-11 v1. Given the traditional role of heuristics, DEG-7-11 v1 can be deployed as an effective evaluation tool. DEG-7-11 v1 was applied to different existing DEGs.

To validate DEG-7-11 v1, Heuristic Evaluation has been conducted by inspecting 15 selected educational games on different topics with the eight heuristics. The assumption is the higher the number of the DEG-7-11 v1 heuristics followed by a DEG, the higher the quality of the DEG is, leading to a higher average player preference rating.

A statistically significant correlation was found between the players' preference ratings of the games and the percentages of the heuristics followed by the games. The study in Chapter 8 inferred that if game designers regard the proposed important features for designing DEGs, the games might attain high rating as evidence revealed in the chapter. It can be said that DEG-7-11 v1 can efficiently guide the development of a successful DEG.

This result could somewhat validate the effectiveness of DEG-7-11 v1. Given the findings of the validation study, it can be argued that the eight heuristics of DEG-7-11 v1 are essentially validated. However, the heuristics had some wording modification to make it more understandable for evaluators.

An interesting observation is that none of the games inspected has followed the heuristic about gender-based adaptation. Future research on identifying underlying causes and remedies for improving the situation is called forth.

9.6.2 Limitations

When considering the importance of individual heuristics, it is noted that they could not be ranked by this study. Although the study showed that there were different percentages of games followed the DEG-7-11 v1 heuristics, the most and the least percentage was not be able to rate the importance of different heuristics such as feature of including rewards as in-game feedback in a DEG is important than the feature of providing different avatars for different genders. Future studies would substantiate the validation both usability and educationally effective of games and could be engaged as the judgment for importance ranking of the heuristics.

As proposed by Nielsen and Molich (1990), heuristic evaluation should be done by more than one evaluator or expert, such as game designer or HCI researchers, because different backgrounds of evaluators can perceive the same system somewhat differently. Due to the lack of resources to involve other HCI researchers, the Heuristic

Evaluation was solely performed by one evaluator that was me. Inter-rater reliability cannot be assessed.

9.7 Overall Summary

It can be concluded that the DEG-7-11 v1 heuristics are an addition of the GameFlow model. The GameFlow itself could be applied to design a game, but not for a DEG for children aged 7-11 years. The DEG-7-11 v1 was developed to bridge the gaps of the GameFlow model by augmenting it.

9.8 Future Work

It is very difficult, if not impossible, to create one set of heuristics that address all different needs of different children by one single game. DEG-7-11 is aimed to be generic for designing an educational game for children aged 7-11 years. However, given the observed gender-, age-, and game experience-related significant differences, the corresponding heuristics may entail further refinements based on more empirical evidence to be gathered in the future.

Based on the systematic evaluation, the importance of DEG-7-11 heuristics could not be ranked. It could not be concluded that which heuristic is more important than which one. The verification process of each heuristic individually is still needed although it takes time to do so, such as creating different games for testing corresponding heuristics individually. However, it is difficult to do so within the time frame of my PhD study. Such verification processes may entail further refinements based on more empirical evidence to be gathered in the future. It might deal with a consideration of the third version of DEG-7-11 or DEG-7-11 v3.

Enhancing memory is one of the developments of cognitive skills that computer games can enhance as mentioned in the above literature reviews. Besides providing the evidence of the effectiveness of DEG-7-11, the two game prototypes were created to prove the benefit of computer games for enhancing memory. It can be inferred that the games can contribute to enhancing children's memory. After playing the game, children could recall the content of food groups. The other benefit of computer games can be changing consumer behavior/attitude. In case of my research work, the children's

attitudes towards foods might be changed as a result of playing the two games, appreciating balanced diets with different food groups. This attitudinal change may help lower the obesity rate of children. However, modifying attitude and behaviour a long-term process and it cannot be validated in this study.

For the future work, I plan to examine more in detail of how usability problems could interfere into learning problems. It is a great challenge to design any kind of learning software, especially games.

Due to the high degree of variation in the type of problems, game designers are often asked or sought to solve, it is beneficial in having a set of guidelines to serve as a starting point for further work on designing DEGs, especially for children games. DEG-7-11 heuristics are valuable to provide game design teams with an HCI-focused set of heuristics that they can use for designing and evaluating DEGs.

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Appendix A: Observation Coding Scheme

Behaviours, both verbal and non-verbal, must be identified during game playing time. To be more readily analysed, structured observations should be prepared. The researcher needs to decide what the focus of the observation would be. Thus, an *observation coding scheme*, a way to record those activities; is needed to be designed (Strathclyde, 2013), what the different things to be focused on and can reflect the problems of the game while playing it.

In 2006, a coding scheme to find both usability and fun problems through observations during young children playing computer games was proposed by Barendregt and Bekker (2006). Their coding scheme is specifically created to code the behavior of young children with computer games in the adventure genre. The coding scheme is presented in Table A.1.

Table A.1 Barendregt and Bekker's Observation Coding Scheme

Code	Short Description	Definition
Coding Scheme Based on Observed Actions With the Game		
ACT	wrong action	An action does not belong in the correct sequence of actions. An action is omitted from the sequence. An action within a sequence is replaced by another action. Actions within the sequence are performed in reversed order.
EXE	execution/motor skill problem	The user has physical problems interacting correctly and in a timely manner with the system.
PAS	passive	The user stops playing and does not move the mouse for more than 5 sec when an action is expected.
IMP	impatience	The user shows impatience by clicking repeatedly on objects that respond slowly, or the user expresses impatience verbally.
STP	subgame stopped	The user stops the subgame before reaching the goal.

Code	Short Description	Definition
Coding Scheme Based on Verbal Utterances or Nonverbal Behavior		
WGO	wrong goal	The user formulates a goal that cannot be achieved in the game.
WEX	wrong explanation	The user gives an explanation of something that has happened in the game, but this explanation is not correct.
DSF	doubt, surprise, frustration	The user indicates: Not being sure whether an action was executed properly. Not understanding an action's effect. The effect of an action was unsatisfactory or frustrating. Having physical problems in executing an action. That executing the action is difficult or uncomfortable.
PUZ	puzzled	The user indicates: Not knowing how to proceed. Not being able to locate a specific function.
REC	recognition	Recognition of error or misunderstanding: The user indicates recognizing a preceding error or misunderstanding.
PER	perception problem	The user indicates not being able to hear or see something clearly.
BOR	bored	The user verbally indicates being bored. The user nonverbally indicates being bored by sighing or yawning.
RAN	random actions	The user performs random actions, indicated verbally or nonverbally.
HLP	help	The user cannot proceed without help and either asks for it or the researcher has to intervene in order to prevent serious problems.
DIS	dislike	The user verbally indicates disliking something.

Although the observation coding scheme was originally created for the genre of adventure games, no specific wordings or content are used. In order to examine how the

coding scheme would be operated practicably for casual games, the genre of the two DEGs of this research project (Chapter 6), it was tested in the Pilot Test. The result confirmed that all codes could be administered properly for casual game genre in the context of this research project. Furthermore, some types of behaviours or events beyond the prepared lists were observed closely and noted, and eventually used to modify the coding scheme. The additional codes were needed in order to observe extensively. They are applied to explore good points of the games rather than only game problems as the original coding scheme already proposed. The additional codes is in Table A.2

Table A.2 Additional Codes for Observation Coding Scheme

Code	Short Description	Definition
Additional Coding Scheme		
TIR	tired	The user verbally/nonverbally indicates tired.
DTR	distracted /annoyed	The user verbally/nonverbally indicates distracted/annoyed because of some features such as silly.
EXC	excited	The user verbally/nonverbally indicates excited such as cool.
REL	relief	The user verbally/nonverbally indicates relief such as sigh.
LIK	like	The user verbally/nonverbally indicates liking such as that's good.
REM	remember	The user verbally/nonverbally indicates remembering/recalling.

The observation was made during the whole period of an empirical session (ninety minutes). During each observation session, about six children were randomly chosen to be observed. The way of conducting the observations used in this study was *Event Sampling (or Frequency Counting)*. It is one of various ways of conducting the observations (Strathclyde, 2013). With Event Sampling, a list of the actions/events/behaviours under investigation which are listed in the coding scheme, is tallied, the amount of observed instances is recorded on a checklist, without considering the chronological order. Table A.3 is the example of actions sampling list.

Table A.3 Example of Event Sampling (Frequency Counting)

Code	Short Description	Frequency Counting					
		Ch1	***Ch2***	***Ch3***	***Ch4***	***Ch5***	***Ch6***
Coding Scheme Based on Observed Actions With the Game							
ACT	wrong action	II			I		
EXE	execution/motor skill problem			III			
PAS	Passive					IIII	
Coding Scheme Based on Verbal Utterances or Nonverbal Behavior							
WGO	wrong goal						III
WEX	wrong explanation	I			II		
DSF	doubt, surprise, frustration	I					

Note: ChX means children number X, scratches stand for the number of times each type of list actions was observed.

Appendix B: Interview Protocol

As mentioned earlier, *Playability Heuristics* (PH) were used to evaluate the playability aspect within games, thus, the coding categories of interview data for evaluating usability and user experience of the games were derived from the GameFlow model; PH of Sweetser and Wyeth (2005). The key words or phrases of each question were identified from the criteria of each element of the GameFlow model (concentration, challenge, player skills, control, clear goals, feedback, and immersion). Also, open ended questions of the interviews to evaluate children's preference for general educational games were formulated.

To construct the questions for interviews, the *memory recall* strategy was adapted. Many factors can affect recall, one of them is motivation. Motivation can encourage a person to perform and succeed in the tasks at hand. Atkinson (1953) concluded that the strength of motivation effected on recall of interrupted and completed tasks. It could be inferred that if the games contain motivating features to inspire children to accomplish the tasks given in the games, children can recall easily some of those features.

Cued recall was particularly used to construct the questions. The researcher gave participants associative cued questions about game's motivating features that they might not originally recall; the participants would be able to eventually recall those features.

In order to gain deeper insights into the effectiveness or problems of the games, some children were randomly chosen to be interviewed after playing the games. A child was invited individually to comment on his/her experiences on the usability and user experience of the games as well as on the preference for general educational games. The child was also free to raise other relevant issues to the game design. The interview protocol is shown as following.

The Interview Protocol

This interviews aim to find out about children experiences after testing the game as well as to see about expectation for general educational games.

The interview is conducted personally with a kid after he/she played the game. The interview would take about ten minutes for individual. Personal interview could remove the problem of influence by their peers. As a precaution, interviews are recorded with a digital recorder. The recordings are saved on computer disks.

There are two parts of initial questions; however some new open-ended questions may be triggered to deeply ask students.

1. The usability and user experience of the games

The first part of an interview tends to focus on the usability and user experience of the games in seven topic areas.

Element	Questions
Concentration	- Can you remember the appearance of the interface of the game? - Please tell me some features that you remember about the following things: pictures, colours (e.g. background colour, characters' colour), text (e.g. text size, text colour, text style), animation effects. - Either positive or negative remembers.
Challenge	- Could you progress through each of the levels of the game? - Please tell me all of the levels that you can remember and tell me how to play each level. - Are there any levels which you could not know how to play? Which level? Please describe the features of the level.
Player Skills	- Have you looked the instruction before playing game? - If you have looked, please tell me the features of the instruction.
Control	- Tell me about the characters and their movements and interactions that you could control over them.
Clear Goals	- Which page of the games let you know the aims of the game? - Do you remember the features of the page?

Element	Questions
	- Please describe briefly.
Feedback	- What feedbacks let you know you progress toward the goals of the game? - What feedbacks you can check the status of your goals?
Immersion	- Is there anything which makes you become less aware of your surroundings? Please describe shortly.

2. The preference for the games.

The second part of an interview focuses on the preference for the games.

What did you remember about **the features of the games** which you just have played and **liked it**? Please list the points or write down everything you can remember in 3 minute.	What did you remember about **the features of the games** which you just have played and **didn't like it**? Please list the points or write down everything you can remember in 3 minute

3. The preference for general educational games.

The third part of an interview focuses on the preference for general educational games.

What did you remember about **the features of educational games** which you have played before and **liked it**? Please list the points or write down everything you can remember in 3 minute.	What did you remember about **the features of educational games** which you have played before and **didn't like it**? Please list the points or write down everything you can remember in 3 minute