A SERIOUS GAME DESIGN FRAMEWORK FOR VOCABULARY LEARNING OF CHILDREN WITH AUTISM

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ABSTRACT

The use of serious games to provide intervention of different skills related to autism has increased in recent years. However, the potential of serious games to provide intervention of vocabulary to autistic children has been underutilised despite its importance in the overall reading comprehension. The task to design serious games for vocabulary learning of these children becomes more challenging as there are no existing serious game design frameworks (SGDFs) to provide guidance throughout the design process. The framework and its components play a vital role as it spells out what needs to be incorporated into the serious games. The main aim of this research is to construct an SGDF to design serious games for these children to learn vocabulary. First, the components related to children with autism and serious games that could constitute a serious-game design were identified from the extensive review of literature on autism and existing SGDFs. Second, the identified components were logically grouped within intra-frameworks and then across the inter-frameworks. An input, process and output (IPO) model was selected as an underlying structure to construct the framework. The components resulting from the intra- and inter-frameworks grouping were logically placed into the phases of IPO model to produce the initial version of the framework. The expert reviews were conducted in an iterative manner for the evaluation of framework from the perspective of academicians and researchers working in the area of serious games, and game designers. An applicability validation was also conducted to assess the application of the framework. The framework was modified and revised version of the framework was produced based on the outcomes of all the evaluations. Third, a serious game design was produced and design was transformed into a serious game prototype to show the logical view of the proposed framework. Fourth, a heuristic evaluation was performed on the prototype using the modified set of heuristics developed as part of this research to improve its overall usability. An experimental

evaluation of the prototype was conducted using single-subject research design to measure the performance in learning vocabulary among autistic children before and after using the prototype. The main finding from expert reviews shows that structure, components and their details of the proposed framework have been effectively refined. The hands-on experience of experts working with framework for its applicability positively reaffirms its practical use. The visual analyses of experimental evaluation of the prototype revealed that the receptive identification based on the average number of correct answers selected by these children across the sessions improved from the baseline (53.97%) to intervention (92.57%) and maintenance (93.73%). It also revealed that the average number of attempts made to identify correct answers across the sessions of each child lowered from baseline (1.9) to intervention (1.1) and maintenance (1.1). The results will help researchers and game designers to design serious games for these children, develop prototypes, and perform its usability evaluation.

ABSTRAK

Penggunaan permainan serius untuk menyediakan campur tangan kemahiran yang berbeza berkaitan dengan autisme telah meningkat pada tahun-tahun kebelakangan ini. Walau bagaimanapun, potensi permainan serius untuk menyediakan campur tangan perbendaharaan kata untuk kanak-kanak ini tidak digunakan sepenuhnya walaupun ianya penting dalam kefahaman membaca keseluruhannya. Tugas untuk mereka bentuk permainan serius untuk pembelajaran perbendaharaan kata kanak-kanak ini menjadi lebih mencabar kerana tidak ada rangka kerja serius permainan reka bentuk (SGDFs) yang sedia ada untuk dijadikan panduan sepanjang proses reka bentuk. Rangka kerja dan komponennya memainkan peranan penting kerana mereka menjelaskan apa yang perlu digabungkan ke dalam permainan yang serius. Tujuan utama kajian ini adalah untuk membina sebuah SGDF untuk mereka bentuk permainan serius bagi kanak-kanak untuk belajar perbendaharaan kata. Pertama, komponen-komponen yang berkaitan dengan kanak-kanak autisme dan permainan serius yang boleh membentuk permainan yang serius telah dikenal pasti daripada kajian yang mendalam kesusasteraan mengenai autisme dan SGDFs sedia ada. Kedua, komponen yang dikenal pasti telah secara logik dikumpulkan dalam intra-rangka kerja dan kemudian di seluruh antara rangka kerja. Input, proses dan model output (IPO) telah dipilih sebagai struktur asas untuk membina rangka kerja. Komponen yang terhasil daripada kumpulan dalam dan antara rangka kerja telah secara logik diletakkan ke dalam fasa model IPO untuk menghasilkan versi awal rangka kerja tersebut. Ulasan pakar telah dijalankan secara lelaran untuk penilaian rangka kerja dari perspektif ahli akademik dan penyelidik yang bekerja dalam bidang permainan yang serius, dan pereka permainan. Satu pengesahan kebolehgunaan juga telah dijalankan untuk menilai permohonan rangka kerja tersebut. Rangka kerja ini telah diubahsuai dan versi semak semula rangka kerja telah dihasilkan berdasarkan hasil semua penilaian. Ketiga, reka bentuk permainan serius telah dihasilkan dan reka bentuk

telah berubah menjadi prototaip permainan serius untuk menunjukkan pandangan yang logik rangka kerja yang dicadangkan. Keempat, penilaian heuristik telah dilakukan ke atas prototaip menggunakan set heuristik yang diubah suai yang dibangunkan sebagai sebahagian daripada kajian ini untuk meningkatkan kebolehgunaan keseluruhannya. Penilaian eksperimen prototaip dijalankan menggunakan reka bentuk kajian satu subjek untuk mengukur prestasi perbendaharaan kata di kalangan kanak-kanak ini sebelum dan selepas pembelajaran menggunakan prototaip. Penemuan utama daripada ulasan pakar menunjukkan bahawa struktur, komponen dan butiran mereka rangka kerja yang dicadangkan itu telah ditapis dengan berkesan. Pengalaman hands-on pakar bekerja dengan rangka kerja untuk kebolehgunaannya secara positif mengesahkan ia praktikal digunakan. Analisis eksperimen prototaip menunjukkan bahawa perbendaharaan kata kanak-kanak ini bertambah baik selepas menggunakan prototaip. Analisis visual penilaian eksperimen terhadap prototaip mendedahkan bahawa penerimaan pengenalpastian berdasarkan purata bilangan jawapan yang betul dipilih oleh kanak-kanak di seluruh sesi meningkat daripada garis dasar (53.97%) kepada campur tangan (92,57%) dan seterusnya, penyelenggaraan (93,73%). Ia juga menunjukkan bahawa purata bilangan percubaan dibuat untuk mengenal pasti jawapan yang betul di seluruh sesi bagi setiap kanak-kanak menurun dari garis dasar (1.9) kepada campur tangan (1.1) dan penyelenggaraan (1.1). Keputusan akan membantu penyelidik dan pereka permainan untuk mereka bentuk permainan serius untuk kanak-kanak ini, membangunkan prototaip, dan melaksanakan penilaian kebolehgunaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

ABA: Applied Behaviour Analysis

AI: Artificial intelligence

ANOVA: Analysis of Variance

APA: American Psychiatric Association

ASD: Autism Spectrum Disorder

CAI: Computer-assisted instruction

CBI: Computer-based intervention

CC: Correlation Coefficient

CDC: Centers for Disease Control and Prevention

CERs: Cause-effect relationships

DPE: Design, play and experience

DSRM: Design science research methodology

DTT: Discrete trial training

GBLAs: Game-based learning attributes

GCs: Game components

HCI: Human-computer interaction

ICC: Intra-class correlation coefficient

IP: Information processing

IPO: Input, process, output

IQ: Intelligent quotient

IRR: Inter-rater reliability

LTM: Long-term memory

MDA: Mechanics, dynamics and aesthetics

MANOVA: Multivariate analysis of variance

MSs: Multimedia systems

NAC: National Autism Center

NAP: Non-overlap of All Pairs

NRC: National Research Council

NLRs: Narrative literature reviews

NPCs: Nonplayer characters

NRP: National reading program

PDD-NOS: Pervasive Development Disorder – Not Otherwise Specified

PRT: Pivotal response training

RQs: Research questions

SGs: Serious games

SGDF: Serious game design framework

SLRs: Systematic literature reviews

SME: Subject matter experts

SPANOVA: Split-plot ANOVA

SRSD: Self-regulated strategy development

SSRD: Single-subject research design

STM: Short-Term Memory

TAM: Technology acceptance model

TD: Typically developing

TEACCH: Treatment and Education of Autistic and Communication Handicapped Children

VIN: Vocabulary instruction

TCIN: Text comprehension instruction

TUI: Tangible user interface

VLEs: Virtual learning environments

VRT: Verbal behaviour therapy

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

This chapter starts with the background of the study whereby research problems are described, followed by the motivation behind doing this research work before a problem statement is presented. The research objectives and research questions related to this research are also presented. The significance behind this research is discussed, scope and limitation of the research are described, followed by details on the research methodology used to conduct all the research chores throughout the study. Lastly, the structure of this thesis is presented.

1.1 Background of the study

Autism is one of the five neurological disorders among children that falls under the umbrella of Autism Spectrum Disorder (ASD) which includes Autism, Asperger Syndrome, Childhood Disintegrative Disorder, Rett Syndrome and Pervasive Development Disorder – Not Otherwise Specified (PDD-NOS). Autism is characterized by impairment in social communication, and restricted or repetitive behaviour. Its symptoms appear during the first three years of a child's life and affect the later course of life. Every child with autism varies from the other in terms of: one may be very verbal, bright and engaged; while another is non-verbal and intellectually challenged (Whalon & Hart, 2011). Research has shown that many parents took their children for the evaluation of delay in language development at a very early age (Dahlgren & Gillberg, 1989; De Giacomo & Fombonne, 1998). Acquisition of a language among children with autism is characterised by dramatic delays; these children can only speak when they are, on an average, 38 months old compared with the average age of 8 to 14 months in typically developing (TD) children (Howlin, 2003).

Reading comprehension is composed of two important and distinct components (Duff & Clarke, 2011; Ricketts, 2011; Whalon, Otaiba, & Delano, 2009): Decoding and Language

Comprehension; if a child is able to decode text and understands it, this ensures that the child is reading (Khowaja & Salim, 2013). According to (Chiang & Lin, 2007), it is considered as one of the important academic skills that children learn at their school. Although children with autism have good decoding skill which is an ability to translate text into speech and is only a part of the reading comprehension, but, these children lack language comprehension skill which is an ability to understand spoken language and it is an essential component of the reading comprehension.

Vocabulary so-called lexicon or meaning of individual words is the most essential and basic component of the language. It is composed of a group of words which provides a building block to develop any language. Children start learning and developing their vocabulary when they are infants, they continue developing their vocabulary as a toddler when they listen to someone speaking and then finally they start speaking. The vocabulary of an individual constantly evolves as they start reading different materials and communicating with others. Learning vocabulary directly influence reading comprehension (Biemiller, 2003). In order to properly understand the text being read, it is important to know 95% of words in the same text (Fukkink, Hulstijn, & Simis, 2005). This indicates that processing at word-level is considered as an essential part of the comprehension.

Children with ASD typically require a one-to-one instruction. Computer-based intervention (CBI), which is widely used in the special education sector, has been suggested as a supporting tool for teachers of children with ASD (Hassan et al., 2011; Higgins & Boone, 1996; Powell, 1996). A number of review articles (Fletcher-Watson, 2014; Khowaja & Salim, 2013; Ramdoss, Lang, et al., 2011; Ramdoss et al., 2012; Ramdoss, Mulloy, et al., 2011) have been written in recent years on the use of CBI for the intervention of different skills related to children with ASD. From the reviews, it was found that the researchers have

conducted various experimental researches on the use of serious games to provide intervention of different skills to these children.

According to Diana (2010) games can be used to provide an interactive learning environment for different literacy skills including reading, writing, listening and speaking. The author has further mentioned that games can also be used to provide learning of various types of communications skills i.e. how to encourage or criticize other, agree with someone or something or on something and explain something to someone, among others. Serious Games (SG) have been designed so that, besides their pure entertainment value, these game convey relevant ideas or messages about various aspects not related to the gaming industry. A serious game is not only associated with the education and learning of new concepts and skills, but can also work as training and simulation of various activities of real life (Bartolomé, Zorrilla, & Zapirain, 2011; de Urturi, Zorrilla, & Zapirain, 2011). In other words, a serious game in its virtual world provides a similar learning environment to the users as what they experienced in their day-to-day life and this is beyond the scope of providing entertainment unlike typical games. Various serious games have been developed in the recent past for these children to learn different skills (Noor, Shahbodin, & Pee, 2012; Zakari, Ma, & Simmons, 2014). The serious games are typically designed based on the existing framework. The use of framework ensures that all the game-related components are considered during the design process; otherwise, it is possible that some components are highly emphasized while some other components may be poorly or not emphasized at all.

A serious game design framework is composed of various components that are integrated together on an underlying structure, communicate with each other and provide a fundamental building block to design an interactive learning environment of the game (Khowaja & Salim, 2014). The components and the structure of framework play a vital role in the design of a

serious game so that the needs of the users are catered to. The components guide on what needs to be incorporated, while the structure guides on how components can be incorporated into the design. This research attempts to investigate and grasp the knowledge and understanding of how the serious game design framework can be constructed to design games for autistic children to learn and improve their vocabulary.

1.2 Research problems

This section discusses research problems pertaining to learning of vocabulary in children with autism, and the use of serious games for these children. Brewer and Hunter (2006) have classified any issues or concerns studied by the researchers as the research gaps. In this section, all such gaps are referred to as research problems. The urge to conduct this research is due to the following gaps found in research:

1.2.1 Fewer studies on CBIs to support children with ASD in the learning of vocabulary

Researchers and practitioners have acknowledged the importance of vocabulary in improving reading comprehension. The trend of writing different types of review papers (systematic literature review paper, survey paper, meta-analysis etc.) by the researchers to investigate a set of questions related to the area of research or particular issues has increased in the recent past. Therefore, in the first phase, an initial search on four databases namely SpringerLink, ACM digital library, ScienceDirect and Google Scholar to retrieve review papers was performed to broaden the understanding on CBIs that have been developed to support these children in the learning of vocabulary. The search did not reveal any review paper which is specific to the learning of vocabulary but it did reveal one related review paper by (Ramdoss, Mulloy, et al., 2011). These authors have targeted all those studies that have used CBI to facilitate autistic children to learn, practice and improve literacy skills

which include reading, writing, and vocabulary. This review paper performed a search in four electronic databases namely Education Resources Information Center (ERIC), Medline, Psychology and Behavioral Sciences Collection, and PsycINFO between 1990 and 2010 (inclusive) using a combination of Boolean terms. This review included twelve studies from which four studies (Bosseler & Massaro, 2003; Massaro & Bosseler, 2006; Moore & Calvert, 2000; Whalen et al., 2010) are related to vocabulary; this shows that not much research has been conducted in this area. Among these four studies, two studies (Bosseler & Massaro, 2003; Massaro & Bosseler, 2006) belong to the same authors and they have used the same CBI. The specific type of CBIs developed or used among these four studies includes multimedia-based applications. This shows that no serious games, tabletop interfaces, virtual reality, tangible user interfaces (TUI) among others have not been exploited for the learning of vocabulary.

In the second phase, the search was performed in nine databases to identify more studies related to the learning of vocabulary through CBI; all databases except ERIC were different from those used by (Ramdoss, Mulloy, et al., 2011). A number of Boolean terms were used to locate primary studies; the results from this search revealed the same primary studies which were found in the review paper by Ramdoss and colleagues. The combination of Boolean terms used in this phase also revealed various studies not related to the learning of vocabulary but the use of CBI for the other skills related to children with ASD. These studies show that authors have more commonly used different CBIs such as serious games and tabletop interfaces. Additionally, a review paper specifically written on serious games developed for these children by (Noor et al., 2012) was also found. This shows that serious games have been highly used to provide CBI of other skills related to children with ASD.

1.2.2 Under-utilization of serious games for vocabulary domain

It is evident from section 1.2.1 that serious games are highly used to assist children with ASD in the learning of various skills including social and communication skills, the concept of money, visual motor coordination, and first-aid learning among others. Most of the studies have revealed positive impact on the learning of these children after using serious games. However, the potential of serious games has not been exploited to teach vocabulary.

1.2.3 Unavailability of the serious game design frameworks

From the search on serious game design framework for children with ASD, it was found that there is only one design framework proposed by (Park, Abirached, & Zhang, 2012) to teach emotions to these children. The framework by Park and colleagues only consider components from the pedagogical perspective that provide guidance on how emotions can be taught step-by-step to these children. The other main components especially from the perspective of autistic children and the components that facilitate in the design of a serious game in general are not considered. Therefore, this framework can be regarded as meeting the minimal requirements in terms of components to design games for these children to learn vocabulary.

1.3 Research Motivation

Based on the research gaps, the following issues are the source of motivation to conduct this research:

1.3.1 Development of CBIs to learn vocabulary

Children with autism enjoy reading material on the computer rather than reading the same material in the book form and show less resistance to using computers (Williams, Wright, Callaghan, & Coughlan, 2002). Moore and Calvert (2000) have reported that children were

very much attentive while they were using a computer than paying attention to the teacher in classroom; they learned 71% of the nouns using a computer than 41% nouns from the teacher . Similarly, in the research conducted by (Bosseler & Massaro, 2003; Massaro & Bosseler, 2006), the researchers found that autistic children had better interactions and learnt more when the face of 3D-animated character called Baldi was shown and the audio of human voice was played compared to the situation when only audio was played. However, there are fewer studies that have investigated the use of CBI for the learning of vocabulary among these children. This requires an investigation of various aspects (a specific problem in the learning of vocabulary, types of vocabulary, strengths and weaknesses in terms of interaction with computers) related to these children so that those aspects are properly exploited in the CBI.

1.3.2 Usefulness of serious games:

Autistic children are visual learners (Layton, 1988) and serious game is one of the types of CBIs that provides a visual and entertainment-based environment to these children where the primary focus is on the education of skills targeted in the serious game. The other types of CBIs may include use of virtual reality environments, augmented reality environments, tabletop interface among others. As highlighted in section 1.2.2, the use of serious games had a positive impact on the learning of various skills among these children. This shows that serious games can also be useful for these children to learn vocabulary. This requires an investigation on how serious games can be developed to facilitate these children to practice, learn and improve their vocabulary.

1.3.3 Components for serious game design framework

The trend to construct specialized serious game design frameworks has increased in the recent past and (Arachchilage & Love, 2013; Denis & Jouvelot, 2005; Ijsselsteijn, Nap, de

Kort, & Poels, 2007; Järvinen, 2009; Moreno-Ger, Burgos, Martínez-Ortiz, Sierra, & Fernández-Manjón, 2008; Shoukry, Sturm, & Galal-Edeen, 2012) are some of the examples. It is evident from the section 1.2.3 that this trend has not been seen in the context of children with ASD as only one framework by Park et al. (2012) was found. The components in the specialized design frameworks take into consideration the users and their needs targeted in the framework in addition to the design of the serious game itself. The framework by Park and colleagues only took into consideration the pedagogical perspective to design serious games for autistic children to learn emotions. Thus, there is a need to investigate and identify main components that can constitute the design of serious games for these children.

In this section, three issues including development of CBI to use for learning vocabulary, usefulness of serious game and components for serious game design framework have been highlighted. These issues have raised concerns that serious games are suitable for these children to learn vocabulary and a framework is needed as it plays a vital role in the design process of the serious game. Therefore, the aim of this research is to construct a framework that can be used as a basis to design vocabulary-based games for autistic children.

1.4 Problem Statement

From the research gaps, it is known that serious games which are widely used for the intervention of other skills have been under-utilized for learning vocabulary. It has been highlighted in the framework by Winn (2008) that designing a serious game is hard. The structure of the framework and its components play a vital role in the overall design. The task of designing a serious game for the vocabulary learning of children with ASD becomes difficult due to the absence of framework.

To pursue the problem statement, this research attempts to deepen the understanding by grasping the knowledge from the perspective of: children with autism, learning of vocabulary among these children, designing a serious game, and existing serious game design frameworks.

1.5 Research Objectives

This research study concentrates on the construction of serious game design framework to design serious games for children with autism to learn vocabulary. Following are the specific objectives to achieve the main objective of this research:

1) To identify components related to children with autism and serious games that constitute a serious game design for these children to learn vocabulary.
2) To construct a serious game design framework using above-identified components.
3) To design and develop a serious game prototype to demonstrate the logical view of the proposed framework.
4) To conduct an experimental study to analyse the performance of autistic children in the learning of vocabulary before and after using the prototype.

1.6 Research Questions

A number of research questions have been designed based on each research objective and each question is answered in one of the chapters mentioned below. The research questions are termed as RQs while the sub-research questions are termed as SRQs.

Objective 1: To identify components related to children with autism and serious games that constitute a serious game design for these children to learn vocabulary.

Chapter 2 – Literature review

RQ1. Which strategies have been used and CBIs developed to teach vocabulary?

SRQ1. Which strategies have been used to teach vocabulary?

SRQ2. Which CBIs have been developed or used to teach vocabulary?

SRQ3. Is teaching using CBI effective? What does the studies from the review show?

RQ2. What are the modalities used in CBIs and the effectiveness of CBIs in the learning, generalisation and maintenance of vocabulary?

SRQ4. Which modalities have been used for the vocabulary of children with ASD?

SRQ5. Are CBIs found in above sub-RQ effective?

SRQ6. Are CBIs effective in the generalisation of vocabulary?

SRQ7. Are CBIs effective in terms of maintenance or retention of vocabulary over a period of time?

SRQ8. Does the use of teacher and CBI together provide better results in the learning of vocabulary?

RQ3. Which autism behaviours are associated with the learning of vocabulary?

RQ4. What are the instruction methods that can be used to teach vocabulary to these children?

RQ5. Which components are used in the existing serious game design frameworks (SGDFs)?

SRQ9. Which components are used in the SGDFs for children with ASD?

SRQ10. Which components are used in the SGDFs for children?

SRQ11. Which components are used in the SGDFs?

RQ7. What are the game-based learning attributes (GBLAs) that could be used in the games?

RQ8. What are the learning theories that can be applied to facilitate these students in the learning of vocabulary?

Objective 2: To construct a serious game design framework using above-identified components.

Chapter 3 – A framework to design vocabulary-based serious game for children with ASD

RQ9. What is the basis used in the construction of the framework?

RQ10. What is the structure of the framework?

RQ11. How were the components logically grouped together and divided into the structure?

RQ12. How can the framework be used to design a serious game?

Objective 3: To design and develop a serious game prototype to demonstrate the logical view of the proposed framework.

Chapter 3 and 5 – Serious game prototype development and evaluation

RQ13. How does a prototype of a game developed?

RQ14. How are the components from revised framework mapped to the prototype?

RQ15. How can a game that is in the early design stage be evaluated for usability problems?

Objective 4: To conduct an experimental study to analyse the performance of autistic children in the learning of vocabulary before and after using the prototype.

Chapter 5 – Serious game prototype development and evaluation

RQ16. Which design is appropriate to evaluate a prototype of the game with the children?

RQ17. How can the learning of vocabulary be measured in these children?

RQ18. Does the learning environment of a game gives impact on the acquisition and retention of vocabulary of these children?

1.7 Significance of research

The task to design serious games for children with autism to learn vocabulary, which was previously done either based on the experience or expertise of all the individuals (academicians, researchers, game designers among others) involved in the design process, is now supported by the serious game design framework (SGDF) proposed in this research. The SGDF guides about the main components and their details that are needed in the design of the serious game and the logical relationships between these components indicate how the information in the serious game flows from one component to another. The outcome from this study, including SGDF and serious game prototype among others, will redound to the benefit of autism community considering that vocabulary plays an important role in the overall success of academic as well as professional life. The increase in the number of children diagnosed with autism in the more recent past and the growing use technology specifically among these children require more effective serious game-based solutions that can be used by these children at any location (classroom. home among others) with minimal guidance and presence of caregivers or teachers.

The serious game design framework from this research can also be used for the evaluation of any existing or current design of serious games to identify the components that have been used in the design. Then, the unused components can be assessed to determine their usefulness in the design of serious game for autistic children.

The construction of serious game design framework in this research is based on the analysis and synthesis of information from the two systematic literature reviews (SLRs) and seven narrative literature reviews (NLRs). The SLRs are based on the strategies and modalities used in the CBIs for children with ASD to learn vocabulary. The NLRs are based on the autism behaviours associated with learning of vocabulary, instruction methods,

existing SGDFs, and the GBLAs. The information from these SLRs and NLRs would benefit game designers and researchers working with children with autism to produce designs of various serious games specifically for these children to learn vocabulary. The information can be used as a reference to design serious games for other skills related to these children.

1.8 Scope and limitations

The research on the development of serious game design framework involves various areas including children with ASD, types of CBIs developed and serious game design frameworks as shown in Figure 1.1. It can be seen that among the various skills of children with ASD, this research focuses on the learning of vocabulary and serious games as a type of CBI.

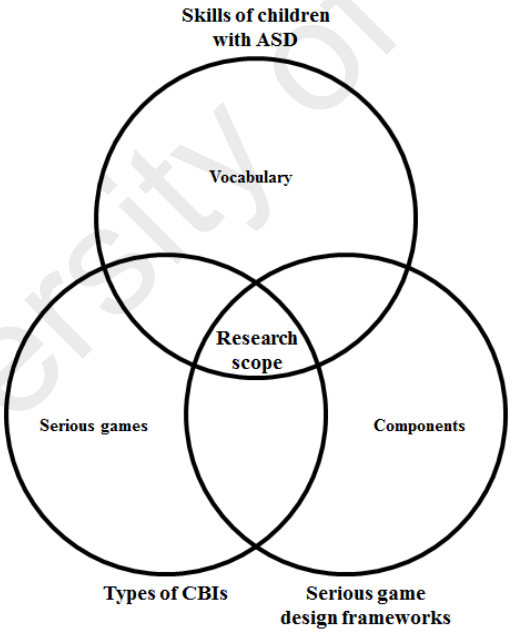

Figure 1.1: Scope of the research

The SGDF proposed in this research only supports the design of serious games aimed to provide intervention of vocabulary to children with autism. This research uses children with mild autism as a sample with ages ranging between 6 and 12 years old boys for the experimental evaluation of prototype developed based on the game designed through the

framework proposed in this research. These children are from the area of Kuala Lumpur, Malaysia. The symptoms, skills and behaviours targeted in the experimental evaluation are highlighted with the dash rectangle in Figure 1.2.

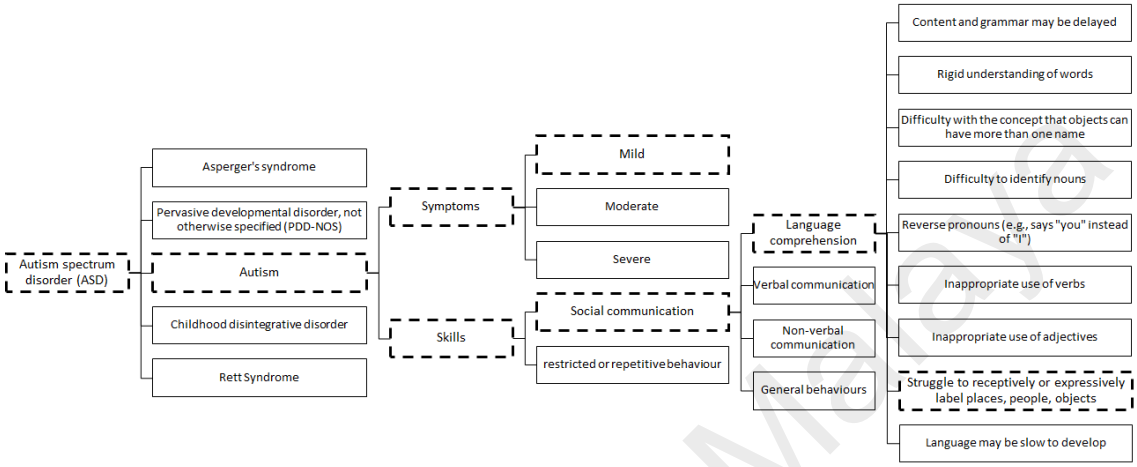

Figure 1.2: symptoms, skills and behaviours targeted in the experimental evaluation of the prototype

All those components related to children with ASD in the proposed framework contain details specific to the learning of vocabulary. Even though the details of these components can be tailored to any other skills related to ASD for the intervention of these children, however, it is not within the scope of this research. E-Games (n.d.) has described five phases to develop a serious game as shown in Figure 1.3; these phases are: 1) concept development, 2) design, 3) implementation, 4) testing, and 5) deployment. The proposed framework concentrates on the design phase of the serious game as surrounded by a round dot rounded rectangle while the remaining phases are beyond the scope of this framework.

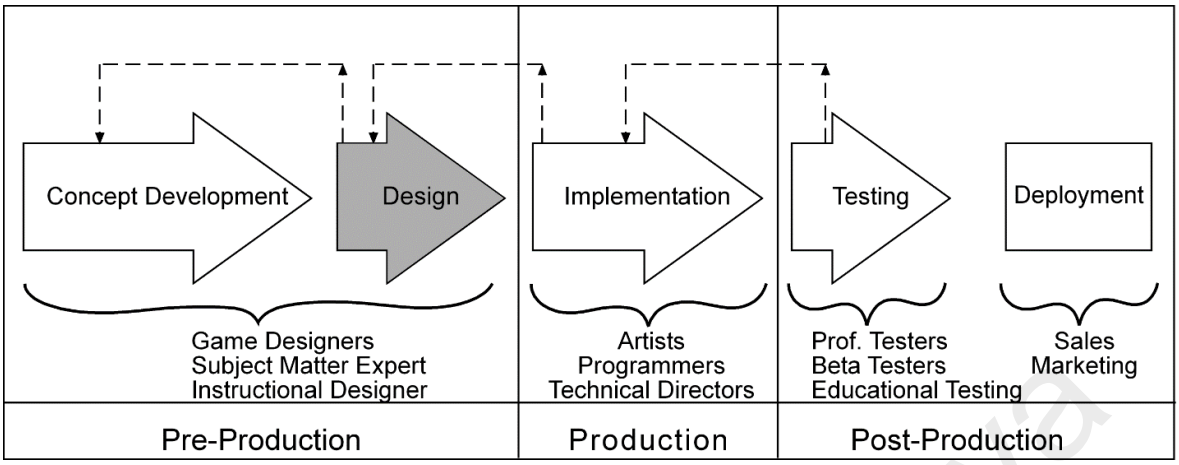

Figure 1.3: Game development process (E-Games, n.d.)

1.9 Research Methodology

The set of activities performed in this research is based on Design Science Research Methodology (DSRM) by (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) as shown in Figure 1.4. This methodology uses a systematic approach to develop and evaluate an artefact to solve a particular problem. The results can be theoretical, practical or both based on the problem targeted in the research. Therefore, DSRM is used in this research with emphasis on the extensive review of the literature to identify the problem, develop an artefact (framework in this research), demonstrate its use, evaluate and communicate the findings with the researchers and relevant audiences. The set of activities based on DSRM carried out in this research are shown in Figure 1.5. The main activities of DSRM and corresponding research questions (RQs) answered are shown at the bottom part of the figure in dashed rectangle and run horizontally, while the sub-activities performed based on each activity run vertically and are shown in a solid rectangle.

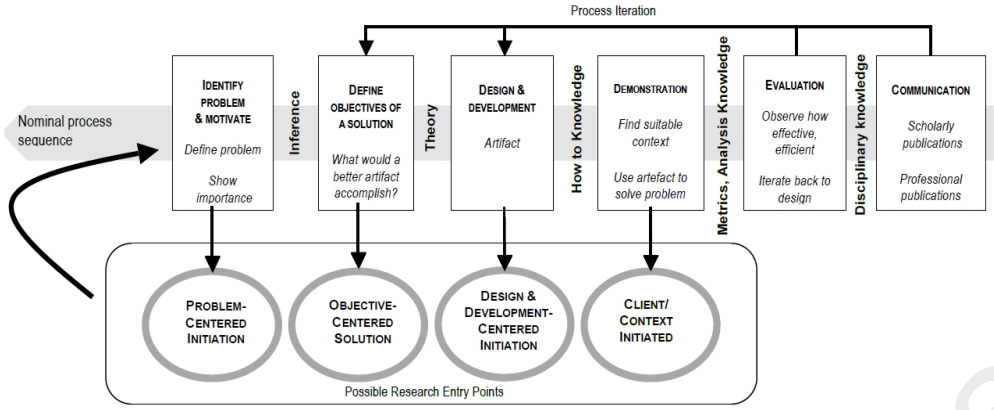

Figure 1.4: The process model of DSRM by (Peffers et al., 2007)

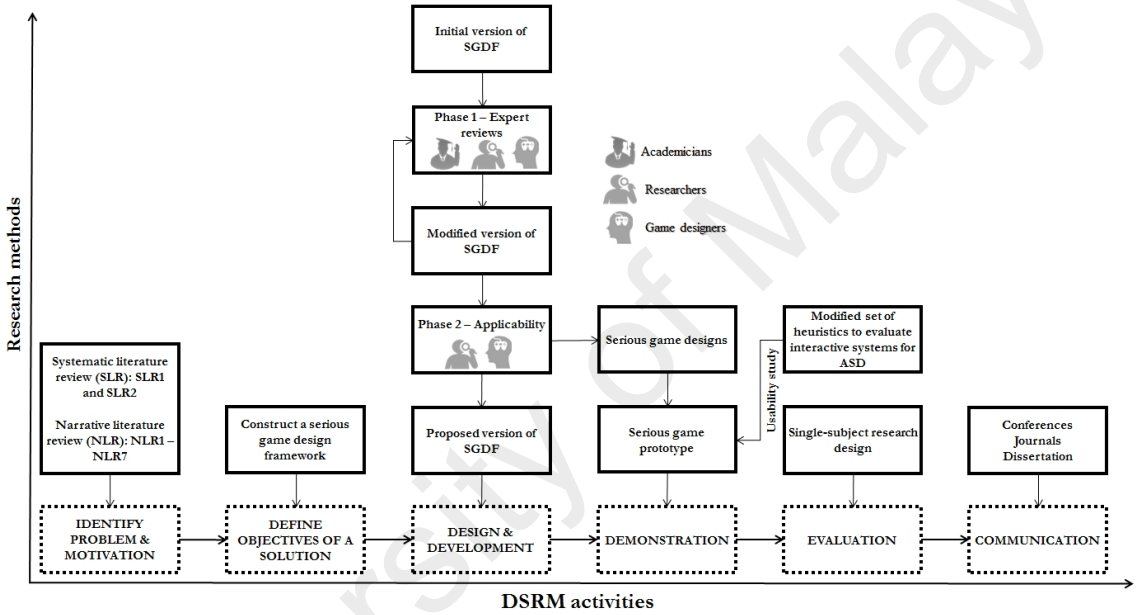

Figure 1.5: DSRM based activities performed and research questions (RQs) answered throughout the research

Each activity of DSRM in the context of this research and how each research method is used during activity is briefly described in the following sub-sections:

1.9.1 Problem identification and motivation

The purpose of this activity is to identify what is the problem (Peffers et al., 2007). The problem can be identified from the review of literature or it can come from the expertise and experience of colleagues and own (past) (Lassenius, Soininen, & Vanhanen, 2001). In this research, an extensive review of literature is used as a basis to identify the problem. The

literature review is based on two SLRs and seven NLRs which are presented in detail in chapters 2, 3, and 4. The SLRs focused on the identification of strategies and modalities used in the CBIs for children with autism to teach vocabulary. The NLRs focused on identification of behaviours associated with learning of vocabulary, suitable instruction methods to teach vocabulary to these children, and serious games developed for these children. It also focused on the components used in the existing serious game design frameworks developed, and the GBLAs used in different frameworks and literature.

1.9.2 Define the objectives of a solution

The first activity is concerned about the identification of the problem (gap), whereas, the purpose of this activity is to determine how the problem should be solved. Considering the focus of this research, chapter 4 describes the objectives of framework in terms of how it can support in designing serious games for autistic children not hitherto addressed.

1.9.3 Design and development

This activity uses the objectives from the previous activity as a basis for the development of an artefact that can solve problems (Peffers et al., 2007). The information gathered from SLRs and NLRs were analysed and used in the development of an artefact which in this research is known as serious game design framework. The framework was iteratively evaluated which led to the refinements in the proposed framework. First, an expert evaluation of the framework was conducted with the academic experts and researchers working in the area of serious games and also game designers. Second, an applicability evaluation of the framework was conducted by asking researchers and game designers to design a serious game based on the proposed framework. Lastly, an applicability survey was conducted with these experts to gather opinion on the use of the framework to design serious games. The comments from all three types of evaluations were used to perform necessary changes in the

proposed framework. The details on the construction and evaluation of the framework are presented in chapter 4.

1.9.4 Demonstration

The purpose of this activity is to prove that the artefact developed in the previous activity works by solving one or more problems (Peffers et al., 2007). This requires a development of serious game prototype as a proof of concept and its usability evaluation to identify and fix usability problems in the serious game before the targeted children start using it.

One of the serious game designs produced during the previous activity was used to develop a serious game prototype. Once a prototype was developed, an approach of heuristic evaluation was used to conduct usability evaluation. A modified set of heuristics was developed based on the extensive review of literature on guidelines in designing an interactive system for these children. The details on the development of the serious game prototype and its usability study are presented in chapter 5.

1.9.5 Evaluation

This activity is about the evaluation of solution developed based on the artefact to solve a problem (Peffers et al., 2007). Therefore, this activity is about the evaluation of the serious game prototype developed in the previous activity to examine its effectiveness in the learning of vocabulary among children with autism.

An experimental evaluation of the prototype was conducted with autistic children using single-subject research design (SSRD) to analyse the performance in the learning vocabulary before and after using the prototype. The comparison between the results from this evaluation and the objectives of the artefact (framework) revealed that the artefact can be used to design

various serious games for these children to learn vocabulary. The details on the evaluation of the prototype are presented in chapter 5.

1.9.6 Communication

The research by Peffers et al. (2007) and Hevner, March, Park, and Ram (2004) have emphasized the importance of communication as a part of research. The construction of the artefact (framework) as a part of this research is a Ph.D. research project; therefore, communication was carried out through conferences and journals related to the area of this research. Furthermore, this dissertation is also a single comprehensive piece of communication.

1.10 Structure of the thesis

Chapter 1: Introduction – introduces a topic of research and provides an overview of the dissertation by providing a brief discussion of the research problem, research objectives, research questions, and the contribution, significance, scope and limitations of the research. It also presents the research methodology followed in this research and the structure of this thesis.

Chapter 2: Components related to children with autism – gives an introduction of the ASD and its social communication behaviours, vocabulary and its strategies, instruction methods, serious games and modalities.

Chapter 3: Components to design serious game for children with autism – provides insight on the existing serious game design frameworks, game-based learning attributes, and all the related theories.

Chapter 4: Construction of serious game design framework – presents a serious game design framework for the vocabulary games for children with autism. It presents an expert evaluation study to validate the framework and incorporate necessary changes suggested by the experts. It also presents an applicability study to demonstrate the working of framework to produce designs of serious games for these children.

Chapter 5: Serious game prototype development and evaluation – presents the serious game prototype developed to teach vocabulary to autistic children. It also presents an expert evaluation study to identify and fix usability problems in the game, followed by an empirical investigation of the prototype with these children.

Chapter 6: Conclusion – gives a review and conclusion of the work, provides implications and future work.

CHAPTER 2: COMPONENTS RELATED TO CHILDREN WITH AUTISM

The review of relevant literature is divided into eight different parts. The first four parts of the literature are discussed in this chapter. The literature on autism and their basic behaviours are reviewed followed by the literature on vocabulary and strategies used to provide vocabulary instruction and the instruction methods for teaching these children. An overview of serious games and its application in autism is presented along with a review of modalities.

2.1 Autism

Autism was first noticed by Kanner (1943) as a shared symptom of a lack of interest in other people. This group of children has been previously given different labels including mental retardation. Since the first recognition of "Early Infantile Autism" by Kanner (1943), the viewpoint of scientific and medical communities towards these children changed dynamically and included other related disorders. According to, Autism is a neurological disorder under the umbrella of Autism Spectrum Disorder (ASD) which includes Autism, Asperger Syndrome, Childhood Disintegrative Disorder (CDD), Pervasive Development Disorder – Not Otherwise Specified (PDD-NOS) and Rett Syndrome (Association, 2000). Autism is characterized by impairments in social communication, and restricted or repetitive behaviour. The symptoms of autism are typically diagnosed in the early stage of infancy and affect regular tasks throughout their lifetime. This neurodevelopment condition has a frequency of one in 110 children in the USA and one in 625 children in Malaysia (Dolah, Wan Yahaya, & Chong, 2011; Rice, 2009). In United States of America (USA), the number of children with autism have increased by more than 78% compared to last decade; this is based on the more recent report by (Centers for Disease Control and Prevention [CDC], n.d.). The details of this report show that in 2000, 1 in every 150 children had autism; in 2012, 1 in every 88 children had autism; and today (2016), it has become more prevalent than in the

recent past with 1 in every 68 children diagnosed with autism. The severity of symptoms among these children are categorized as mild, moderate or severe (2000). The children diagnosed as mild are referred to as high functioning autism spectrum disorder (HFASD) where the children diagnosed as severe are referred to as low functioning autism spectrum disorder (LFASD). The four disorders namely Asperger's syndrome, PDD-NOS, CDD and Rett syndrome are briefly described below.

Asperger's syndrome is also part of the spectrum but it's considered to be at the mild side of the autism spectrum. A child who is diagnosed with this disorder have significant difficulties in terms of social interaction and nonverbal communication with others (Volkmar & Klin, 2000). These children have shown characteristics of having normal language and intelligence. They may speak non-stop on their topic of interest but face difficulties in the area mentioned by the Volkmar & Klin.

Pervasive developmental disorder, not otherwise specified (PDD-NOS) is another disorder that falls under the umbrella of ASD (2000). The term of pervasive developmental disorder (PDD) and ASD have been interchangeably used in the past (Autism Speaks, n.d.). The children or adult were diagnosed with PDD-NOS when the full criteria of neither the autistic disorder nor the Asperger's syndrome were met.

Childhood disintegrative disorder (CDD) is considered as the most severe and rare part of the spectrum; CDD is also sometimes also referred to as a Heller's syndrome and disintegrative psychosis. The children diagnosed with this disorder learn various skills like a typically developing children but then start to lose skills including social, language and mental; this happens within the age of 3 and 4 (Malhotra & Gupta, 1999). These children share the similarities with children with autism and are considered to have low

functioning form of it (McPartland & Volkmar, 2012; Venkat, Jauch, Russell, Crist, & Farrell, 2012).

Rett syndrome is neurological disorder which typically affects the girls than the boys (WebMD, n.d.). The severity of the symptoms are very high. The Rett syndrome was classified under the ASD as the children diagnosed with this syndrome did not show the sign of language and communication skills i.e. same as of autistic disorder. Additionally, these children also had: 1) slower growth of their brain, 2) problems with the motor movement, 3) difficulty to breathe properly, and 4) difficulty to move muscles and their coordination.

The fifth version of Diagnostic and Statistical Manual of Mental Disorders referred to as DSM-5 was published on 18th May 2013 (Association, 2013). The DSM-5 superseded the publication of DSM-IV-TR (2000). In the United States the DSM-5 serves as a universal authority for psychiatric diagnoses. With the release of DSM-5, the four separate diagnoses which include autistic disorder, Asperger's disorder, CDD, and PDD-NOS are now combined under the diagnosis of ASD. Furthermore, the DSM-5 diagnosis of ASD no longer includes communication as a separate criterion, and has merged social interaction and communication (verbal and non-verbal) into one category (Kulage, Smaldone, & Cohn, 2014). After the discovery of genetic cause behind the Rett syndrome, it was excluded from the umbrella of ASD in DSM-5. The symptoms of type mild of is replaced with “requiring support”, while moderate is replaced with “requiring substantial support” and severe is replaced with “requiring very substantial support”.

Children with autism often face problems in receptive language, expressive language or pragmatic skills which create hindrance for them to socialize or learn from others (Wing, 1997). These children encounter problems in receptive language when they are unable to

understand the needs, feelings and ideas of others when they hear or read. The expressive language difficulties occur when they are unable to tell others regarding their feelings, needs and ideas due to limited speech. These children face problems in pragmatic language when they talk inappropriately while they are socializing with others. If these children are unable to gain communication skills, there is a possibility that they may express and present themselves negatively in front of others through their behaviours such as aggression, withdrawal, tantrum and self-stimulation. These problems in the communication of autistic children are often more common and severe than the children's intelligent quotient (IQ) would predict and many of them may even be unable to develop appropriate communication abilities (Seltzer, Shattuck, Abbeduto, & Greenberg, 2004).

Every child with autism is different individually, the behaviours may vary from one child to another: one may be very verbal, bright and engaged; while another can be non-verbal and intellectually challenged (Whalon & Hart, 2011). These children often have great difficulties in making sense of the world, in particular the social world; however, that is not to imply that there is no meaning to the lives of people with autism, rather that socially constructed meaning is difficult, and the less socially constructed the meaning is, the greater the difficulty.

It is often difficult to acknowledge that children with autism can have strengths apart from their weaknesses and the unusual behaviours they show. Thus, it is important to identify those strengths and use them during the time period when intervention is being provided to an individual child. Few of these children may have visual reasoning skills which is also confirmed by their IQ scores (Mayes & Calhoun, 2003). These visual skills allow them to easily work on puzzles, represent textual information in the form of graphs and pictures to memorize contents and learn. Some of the children have abilities to read and may learn to

decode text without any guidance (Mirenda, 2003). A small number of children have more capabilities than their peers in the area of music, art or math. Many children thrive and work on a regular routine and follow the same sequence.

Each child with autism may have a different set of behaviours than the other child. The Table 2.1 shows the list of behaviours specific to communication skills that have been compiled and consolidated from various sources (Rocky Point Academy, 1997; Centers for Disease Control and Prevention [CDC], n.d.; Association, 2000; Bosseler & Massaro, 2003; Johnson, 2004) among others, rather than taking it from one school of thought. A number of centres and academies have been opened in different countries to help children and adults with ASD. These sources also have their websites on which useful information pertaining to ASD is made available to public. The behaviours mentioned on their websites were also added into the compiled list. In this research, the compiled list of behaviours was classified into four categories based on the similarities between behaviours. These categories are: 1) language comprehension, 2) verbal communication, 3) non-verbal communication and 4) general behaviours.

Table 2.1: Categorization of behaviours associated with social-communication skills (Rocky Point Academy, 1997; Centers for Disease Control and Prevention [CDC], n.d.; Association, 2000; Bosseler & Massaro, 2003; Johnson, 2004)

Language comprehension	Verbal communication	Non-verbal communication	General behaviours
1. Content and grammar may be delayed 2. Rigid understanding of words 3. Difficulty with the concept that objects can have more than one name	1. Speech may be delayed, or there may be no speech at all 2. Might not know how to start, sustain, or end verbal conversations 3. Frequently use echolalia	1. No effort to use non-verbal communication 2. Use fewer gestures 3. Difficulty to follow directions 4. Appear not to hear at times 5. Unable to point or wave	1. No response in normal teaching methods 2. Less likely to share experiences 3. Give unrelated answers to questions

4. Difficulty to identify nouns 5. Reverse pronouns (e.g., says "you" instead of "I") 6. Inappropriate use of verbs 7. Inappropriate use of adjectives 8. Struggle to receptively or expressively label places, people, objects 9. Language may be slow to develop	(repeating words of others) 4. Show unusual tone of voice (e.g. Monotone, robotic, or high pitch) 5. No consistent response to name 6. Unable to express wants and needs 7. Talk in a flat, robot-like, or sing-song voice 8. Less likely to make comments or ask questions 9. Less likely to make bids for social attention	6. No accurate interpretation of puns, sarcasm, idioms, etc. 7. Do not pretend in play 8. Do not understand jokes, sarcasms, or teasings	

2.2 Vocabulary

The focus of this research is to provide learning of vocabulary to children with autism; therefore, in this section, a review is carried out to gain further insight on vocabulary and research works that have been carried out related to ASD. The ultimate goal of reading is the comprehension of text being read (Torgesen, 2002) and is considered as “the most important academic skill learned in school” (Mastropieri & Scruggs, 1997, p. 1). Reading comprehension is composed of two important components; Decoding and Language Comprehension (Duff & Clarke, 2011; Ricketts, 2011). The first component is decoding; the ability to translate text into speech and is only a part of reading comprehension. The second and most essential component is the language comprehension or the ability to understand spoken language. If a child is able to decode text and understand; it ensures that the child is reading (Browder, Wakeman, Spooner, Ahlgrim-Delzell, & Algozzine, 2006; Chiang & Lin, 2007; Ricketts, 2011). It involves various processes which include: visual perception in

discriminating printed letters, identifying letters as the components of words, and then interpreting the meaning of these words.

Vocabulary is the most essential and basic component of the language. It is composed of groups of words which provide building blocks to develop any language. Children start learning and developing their vocabulary when they are infants, they continue developing their vocabulary as a toddler when they listen to someone speaking and then finally they start speaking. The vocabulary of an individual constantly evolves as they start reading different materials and communicating with others. Learning vocabulary directly influences reading comprehension (Biemiller, 2003).

Vocabulary among children varies in terms of the number of words they know and the type of words they know (Baker, Simmons, & Kameenui, 1995). The size and acquisition rate of vocabulary plays a vital role in the success of instructional program used to teach vocabulary to children. Teachers measure the progress of their students over a certain period of time to identify the effectiveness of the program for instruction. Researchers have not precisely mentioned granularity of a word (Baumann, Kame'enui, & Ash, 2003), therefore, a method is required in order to find out how many words are known by the children. One of the important question is to consider knowing one word means knowing all its definitions or does each definition of the word counted as knowing one word. For example, a shape can be considered as an object like a square, or it can mean someone gets into a good shape. Another question to ponder is: do various suffixes and forms of words be counted individually or are they considered as a one word? For example, the words: go, goes, going, gone, and went could refer to the same information. It is not clearly mentioned by the researchers how these words are to be counted towards the vocabulary size of an individual, nor, instructions are provided to such extent that learners can master all possible forms of any specific root word.

In terms of communication skills of children with autism, some may be exceedingly talkative, some may not be able to talk; however, they may recognize spoken words and can identify a matching picture related to it. Some of them may be able to type words in order to communicate and convey messages to someone which also shows that they are able to recall words from their memory and spell them. While children with autism are good in learning material when it is presented through visuals, some of them have a higher visual processing abilities than the typically developing children of the same age (Caron, Mottron, Rainville, & Chouinard, 2004). Combination of text and picture provide effective mode of communication and instruction to children with autism as they can memorize a word and its meaning while it is being spoken.

According to the research conducted by Baker et al. (1995), autistic children can become independent learner of vocabulary if an appropriate method of instruction is used to teach new words. The authors have suggested a few ideas for effective vocabulary learning that can be adapted by these children. Sufficient practice of vocabulary should be provided so that they can exercise and learn, and the children's background knowledge should be activated as it can facilitate them to effectively learn new words. The ease with which individual word can be learned directly influences the depth at which it shall be taught. A word which represents an object and has a corresponding picture associated with it is easy to be comprehended and learned by these children. However, a word describing a concept and does not have a picture to represent it is difficult to be comprehended and learned. According to Stahl (2005), different instructional techniques shall be used to teach individual words. The author has further recommended that vocabulary instruction shall include both: definitional activities as well as learning the words in a specific context. Definitional activities include teaching synonyms, antonyms, rewriting definitions of the word learned, providing different

examples, and comparing and contrasting new words with other words. Learning words using instruction in a context include constructing a sentence using a new word, and discussing different meanings of the same word when it is used in different sentences.

Autistic children require specialized instruction, therefore, regardless of the contents to be taught to these children, it is necessary to understand which techniques have been used by the teachers and researchers to motivate these children so that they remain focused on the learning. A systematic literature review (SLR) on reading comprehension for children with autism was carried out in order to identify the: 1) strategies used in the studies, and 2) potential benefits of using CBI to teach reading comprehension with the above-mentioned strategies. The review initially started with focus on the studies related to language comprehension of reading comprehension but due to limited number of studies found, the focus was expanded to gather more information by adding decoding aspect of reading comprehension in the review as well. This SLR work has been published in a journal and the article is appended in appendix A, while the following sub-section provides the summary of the SLR.

2.2.1 SLR on strategies used for the vocabulary instruction of children with ASD

Following are the key findings from the SLR conducted on strategies and CBIs:

1. Multimedia instruction and explicit instruction are widely used strategies to teach vocabulary to children with autism.
2. The use of CBI is very promising; it is based on the significant improvement between the results of pre-test and post-test.

3. Very few types of CBIs have been developed for the vocabulary instruction; these CBIs include multimedia-based application and the use of 3D computer-animated agent for the interaction with autistic children.

2.3 Instruction methods

Children with autism have different learning pace compared to typically developing children (Volkmar, Lord, Bailey, Schultz, & Klin, 2004). It is important for teachers to identify strong and weak points of each individual child and then make a decision on the use of intervention that is appropriate for each child. Iovannone, Dunlap, Huber, and Kincaid (2003) have provided a few recommendations for effective instruction which include: specialized curriculum for children, lesson should be properly structured and systematic delivery of material to meet requirements of every individual. There are a few techniques which allow these children to stay focused on the task, repeatedly do the practice, and learn (Marks et al., 2003). These techniques include visual schedule, allowing children to spend more time on the tasks and use specially modified or developed material for them.

R. L. Simpson, de Boer-Ott, and Smith-Myles (2003) have recommended various methods that can be used to provide effective instruction to children with autism. The authors have suggested that: 1) each task shall be divided into smaller parts and taught at incremental level so that they can smoothly progress towards success. 2) Instruction should make use of words which are not only easy to understand and learn but they are also familiar to these children. 3) When instructional prompts are used, they should be faded away gradually. 4) The systematic learning with different materials, settings and people should be provided to improve the learning of a child. 5) A data collection needs to be done in parallel so that further decision on their instructional programs can be made. 6) It is important to give rewards to an individual child when they respond to the question correctly and reinforcement for the

behaviour and learning effort. 7) Lastly, the teacher of autistic children can adapt these recommendations that can be implemented in any CBI.

Applied Behaviour Analysis (ABA) is a methodology which allows a teacher to observe the behaviour of an individual child and implement different methods to facilitate the individual child in learning and improving those behaviours. ABA provides an effective intervention for autism that has been empirically validated (Schreibman & Ingersoll, 2005). This methodology provides provisions to modify intervention plan as per the needs of an individual, timely measurement and assessment of individual's performance as the intervention is adjusted. It plays a vital role in various areas which include: instructional design, followed by motivation and lastly assessment of an individual (Dunlap, Kern, & Worcester, 2001). The most common trends which impact children with autism include discrete trial training (DTT), treatment and education of autistic and communication handicapped children (TEACCH), incidental teaching, pivotal response training, and verbal response training (National Autism National Autism Center 2009). These common trends are briefly discussed below:

2.3.1 Discrete trial training (DTT):

Discrete trial training (DTT) is a method of instruction which follows the principles of ABA; it is recommended as one of the effective method to teach various skills to children. This method use a single trial also called an instruction cycle for the behaviours targeted in the intervention. These trials are not only clearly defined but also use systematic approach and are measurable (Ferraioli, Hughes, & Smith, 2005); for instance, a trial can be used to teach receptive identification of an apple. The child can demonstrate his response by pointing to the location of an apple when the child hears a request "Where is an apple?" These individual trials can be repeated a number of times one after another, several times during a

day or over a period of several days or even longer duration until the behaviour is mastered. There are five parts of each trial in which first four parts are mandatory while the last part is optional (T. Smith, 2001):

- Discriminative stimulus or cue: the instruction or environmental cue is given by the teacher to initiate a trial and inform the child what they are supposed to do.
- Prompting stimulus: provide assistance to the child so that they can correctly answer the question asked; the prompts slowly and gradually fade away with the passage of time until the child can independently answer to the cue without any prompt.
- Response: is the behaviour shown by an individual child after a short period of time when the prompt or cue was provided.
- Reinforcing stimulus or consequence: consequences are delivered to the child in response to prompt. It is usually a positive acknowledgement in the form of verbal and written praise, limited access to the games or toys of their preference for a while so as to motivate them.
- Inter-trial interval: is the short period of time once the current trial has ended and before the next trial begins.

Prompts can be provided in various different forms, for instance, it can be gestural, physical, verbal, textual, pictorial, tactile, or positional (Ferraioli et al., 2005). The role of a teacher can be replaced or complemented by the use of computers. For the investigation in this research, components of the DTT methodology are employed in the serious game.

2.3.2 Treatment and Education of Autistic and related Communication Handicapped Children (TEACCH):

The TEACCH program was initiated in Chapel Hill, North Carolina at the University of North Carolina as a method to include families and professionals in collaboration to educate children with autism. The program began in 1964 and since then it has been continuously providing clinical support to individuals with ASD throughout their lifespan, and contributing to the field of research as well (Mesibov & Shea, 2010). The aim of TEACCH program as described by Tutt, Powell, and Thornton (2006) is to improve both social interaction and communication by means of a specially created environment in which the child with autism can function through a specially adapted teaching approach. The specialized teaching approach and the environment referred to by the authors include a workstation dedicated to each child to work on and a specific area reserved in the classroom where an activity can occur. Minimal distractions, visuals for schedules and communication, and frequent assessment with clear understanding from the teacher on what needs to be taught next to the child are all part of the program's practices. Additionally, the importance of communication and cooperation between the school and the child's home is highly stressed as the parent is seen as an expert who knows the child since their birth while the teacher is seen as an expert who provides instruction on the regular basis to the child. The teacher and family work together to support the learning and interests of the child, and the strengths of the child are focused on rather than the deficits (Mesibov & Shea, 2010).

TEACCH is listed as an emerging intervention by (National Autism National Autism Center 2009), as the number of studies on the program's efficacy is limited. This did not allow for enough evidence to meet higher standards or to be established. However, a child with ASD can be more successful when the teacher using TEACCH method follows a

structured approach and provides a schedule of an entire day to reduce anxiety and allow the child to know what would happen next (TEACCH Structured teaching staff, 2010).

2.3.3 Incidental Teaching

Incidental teaching is a process in which a child initiates an episode of learning by providing an indication of what the child wants to learn to their teacher in some way. For instance, when the child wants to play with a toy or be a part of an activity, requires attention of either their elders or more typically developing children, makes some form of commenting about an item, asks a question, or shows an accomplishment. However, some children my face difficulties to initiate this interaction; therefore, a teacher may provide more opportunities to these children by using attractive toys, may interact using a toy that the child prefers, may request a play turn, or may set up an environment so that initiation is required for access (for instance, different items are visible to the child but they are not reachable). Once an initiation is established, the teacher builds on this by giving prompts that are level appropriate to the child; this is done to extend and continue the interaction with the child. For example, to increase language responses, a teacher may prompt by asking if a child wants to have a toy. If a child does not respond appropriately, prompts are increased until the appropriate response is given by the child. Once an interactive session has started with the child, the teacher waits until an initiation occurs by the child to provide an incident for further teaching (McGee, Krantz, & McClannahan, 1986; McGee, Morrier, & Daly, 1999; Miranda-Linne & Melin, 1992).

The National Standards Report (National Autism National Autism Center 2009) included incidental teaching as a naturalistic teaching strategy. According to the report, it is an established practice that provides a boost in communication, interpersonal, learning readiness or play for children from 0-9 years of age.

2.3.4 Pivotal response training (PRT)

Pivotal response training (PRT), sometimes also known as pivotal response therapy (PRT) or pivotal response treatment (PRT) by Koegel, Openden, Fredeen, and Koegel (2006), is an ABA driven behavioural intervention of autism in which a child initiates and becomes part of the intervention to play and learn. The use of the term pivotal indicates that this intervention is likely to make positive impact on the learning skills of the child; this would allow the child to use various skills than the ones targeted in the PRT based intervention (Coolican, Smith, & Bryson, 2010; I. M. Smith et al., 2010). The goal of PRT is to facilitate a child in the development of social communication skills, language skills and relief from disruptive self-stimulatory behaviours. PRT concentrates on the development of four pivotal skills in children with autism: 1) provide motivation to socialize with others, 2) responding to multiple cues, 3) self-management of own behaviours, and 4) self-initiation of behaviours when needed. It is considered as an established practice, and is stated to target children of ages 3-9 (National Autism National Autism Center 2009).

2.3.5 Verbal behaviour therapy (VRT)

Verbal behaviour therapy (VRT) or sometimes known as verbal response training (VRT) is based on the principles of ABA and theories of behaviourism by (Skinner, 1957). This therapy is used to teach interpersonal, communication, learning readiness, and playing skills to children with autism and motivates them to learn by connecting multiple words together with their purpose. This allows them to understand and learn ‘why’ specific words are used and how these words can be used to request an object of their interest or obtain any other result. The author has divided language into four operands or types where each operand has its own purpose; the intervention is based on VRT and focuses on four types of operands:

1. Mand: is used to request something. For instance a picture of an apple can be used to request an apple.
2. Tact: is used to draw attention towards something or comment about it. For instance, pointing to a school bus to draw attention towards the bus.
3. Intraverbal: is the use of word to answer a question raised to a child or otherwise response to a question. For instance, a response to the question "where can you buy an apple?" can be "grocery store".
4. Echoic: is a word that is repeated or echoed again and again.

The therapy begins by teaching mand which is considered as the most basic type of language among others. A child is given a training that saying a word like 'apple' can result in getting an apple to eat. The therapist or teacher can reinforce the learning by repeating the word 'apple' in front of child and also giving them an apple. To improve learning of this word, they can use the word in the same or a similar context.

Another concept is given by Sundberg and Michael (2001) which made use of the original work by Skinner (1957) and introduced the concept of tact, which is naming, where a child may be able to name something, but does not use their language to control the environment as they do when using a mand. The same word can be both a mand and a tact, but the usage of it makes the difference. Proponents of verbal behaviour training stated that, to simply teach the child to name (teaching them tacts) does not mean they have language; using language to manipulate the environment also does not demonstrate growth in language; the ability to use language both to name and manipulate the environment is the true key (Autism Speaks 2012).

2.3.6 Discussion

All the instruction methods discussed in this section are summarized in Table 2.2 along with the age group of children with autism for which individual method is more beneficial along with their advantages and disadvantages.

Table 2.2: Summary of Instructional Methods

Name	Ages	Advantages	Disadvantages
Discrete Trial Training (DTT)	0 – 21	Useful for basic language skills, numbers, letters, colours etc. Teacher-controlled Little thinking involved Easy to assess the data	Prompt dependency Need to reprogram for spontaneous skill use Doesn't build fluency
Treatment and Education of Autistic and related Communication Handicapped Children (TEACCH)	0 – 18	Independence Predictability Routine Structure Consistency	Social interaction and verbal communication are not emphasized Does not promote interaction with typical peers
Incidental Teaching	0 – 9	Can be done anytime, anywhere, by anyone Does not require massive training Workable in a developmental classroom setting Short episodes Natural, activity-based Spill-over to play skills Less protest/escape/aversive control Encourages spontaneous skill use	Depends on engagement Cannot control number of trials/data analysis issues Teacher must remain hyper vigilant Must create opportunities
Pivotal Response Training	3 – 9	Child initiates Natural reinforcers Increased motivation Deters inappropriate behaviour	Labour intensive Staff must be adequately trained in the method
Verbal Response Training		Assessment of basic language and learning skills (ABLLS) allows for tracking of a child's progress	Cost may be high to the school districts Labour intensive Requires small staff to pupil ratios

	Useful verbal operators May be used at school and in the home

2.4 Modalities

During the review of studies as a part of SLR on strategies (section), the study by (Bosseler & Massaro, 2003) has emphasized to further investigate the impact of using multiple modalities together on the language learning of children with autism. The research on ASD has shown that these children often exhibit co-occurring sensory processing problems for which they are provided intervention to self-regulate themselves in the day-to-day life (Case-Smith, Weaver, & Fristad, 2014). Although the problems associated with the sensory processing are neither universal nor specific to ASD but, the prevalence of such abnormalities in these children is relatively high (Dawson & Watling, 2000). Therefore, the perception about the modalities supported by the CBI and its use among these children may vary from one child to another. Therefore, there is a need to conduct a review of modalities that have been incorporated in the serious games and find out the effectiveness of using these modalities in the serious games for these children. Thus, the approach of SLR was also followed to investigate the use of modalities in CBIs for these children and the support in the generalisation and maintenance of skills learned.

Children with ASD require an excessive number of one-to-one instructions. Computer-based intervention (CBI), which is widely used in special education sector, has been suggested as a supporting tool for teachers of children with ASD (Higgins & Boone, 1996; Powell, 1996). CBI for children with ASD utilises different modalities (text, images, audio and others) for the interaction with these children. These children learn by using one or more of the modalities available in CBI (Reiff, 1992). Modality is defined as “the type of communication channel used to convey or acquire information. It also covers the way an idea

is expressed or perceived, or the manner an action is performed" (Nigay & Coutaz, 1993). Humans use one of their senses to perceive information presented to them in the natural environment. The human also use actuators such as body, face, hands and voice to act upon the information. When two people interact with each other, one understands the actions performed by the actuators of the other person through his or her sensors. This process is illustrated in Figure 3.1. This figure is logically divided into two halves; the right side indicates the originator who performs some actions and the left side shows the recipient who perceives that information. Computers are able to interpret speech, hand gestures and other actions. There are a few computer-sensory modalities such as automated speech recognition and computer vision, which imitate the human sensor modalities. However, computers have certain sensory modalities that humans do not have. For instance, computers are able to monitor the electrical activities inside the human brain and track eye movements of users who use the system. Computers are able to perceive many human action modalities.

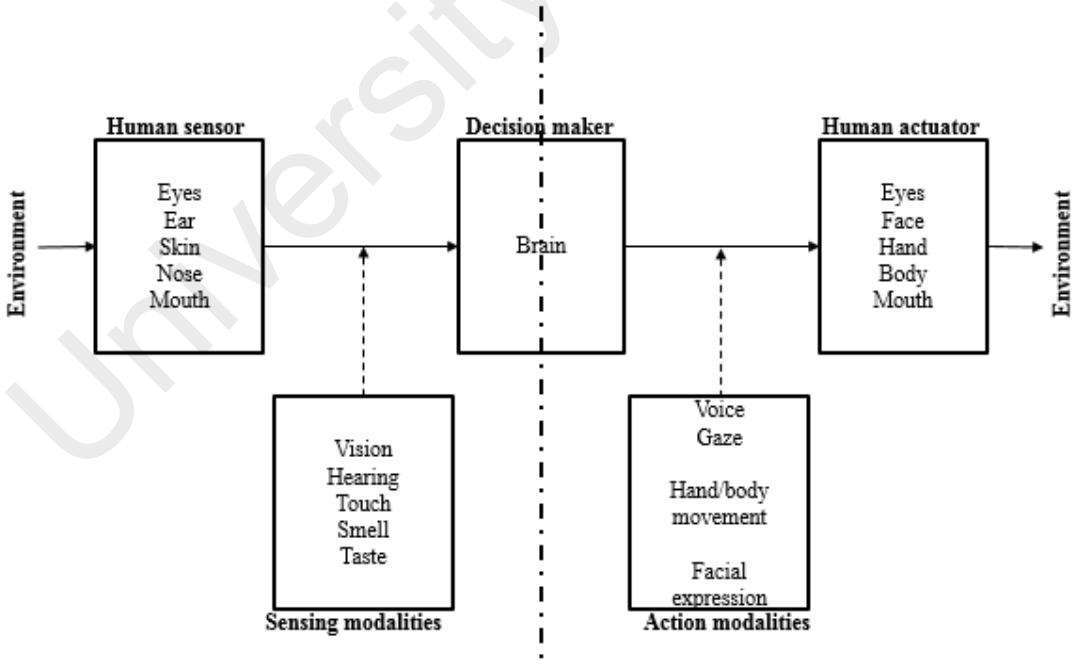

Figure 2.1: Human-to-human interaction redrawn from (Sharma, Pavlovic, & Huang, 1998)

The development of multimodal interfaces has progressed over the last few years as researchers tried to shift their area of interest from specialised to more generalised, robust and transparent interfaces (Benoit, Martin, Pelachaud, Schomaker, & Suhm, 2000; Oviatt et al., 2000). This change stems from the realisation that communication between humans and their working environment is naturally multimodal, i.e. a person talks about an object while looking at it and pointing to it with his or her fingers. At the same time, humans also observe what others are saying and try to guess their feelings. It is highlighted in the review by Oviatt (2012) that the term 'multimodal system' refers to a system in which multimodal interface is implemented. However, considering the domain of this research where system is used for the intervention of children with ASD, the term CBI will be used throughout the paper.

The focus of review in this section is on two types of modalities: 1) human action modalities (voice, hand/body movement, facial expression, gaze and others); and 2) computer sensory modalities (audio, video, tactile, force, motion and others).

An important feature of the CBIs is facilitating children with ASD in the generalisation and maintenance of skills learned through the CBIs. It is because many of these children face difficulties in 1) generalising the skills learned, i.e. transferring skills learnt in one setting or situation to untrained settings or situations, and/or 2) maintaining skills over time, i.e. retention of skills over a period of time (National Research National Autism Center NAC, 2001). Given the importance of language comprehension skills as well as the pros and cons of all the modalities for children with ASD, there is a need for effective CBIs using different modalities for language comprehension and the support in the generalisation and maintenance of skills learned; hence, a systematic review focusing on these aspects is conducted in this section.

2.5 SLR on the use of modalities in CBIs for children with ASD

2.5.1 Related work

A search of literature reviews related to CBI for language comprehension skills of children with ASD was carried out. In particular, focus was placed on studies that covered investigation of modalities. The use of these searching criteria over the internet did not return any meaningful results, except for two systematic reviews. Both of these are briefly summarised in the following paragraphs.

Ramdoss, Mulloy, et al. (2011) carried out a systematic review of studies in which researchers used CBIs to improve the literacy skills (e.g. reading, writing, and vocabulary) of students with autism spectrum disorder (ASD). The authors reviewed studies published between 1990 and 2010. Among the various areas of literacy skills, the focus of research studies was on sentence and word construction, phonological awareness, reading, receptive and expressive language, and vocabulary development, among others. These authors found that the use of CBI for developing literacy skills of children with ASD is a promising practice. In comparison with our review, theirs focused on finding CBIs developed or used and the relevant information, including features, availability, price, and CBI requirements.

Khowaja and Salim (2013) conducted a systematic review of strategies adopted by the national reading program (NRP) and CBIs for reading comprehension of children with autism, focusing on vocabulary instruction and text comprehension instruction; the studies reviewed were published between 2000 and 2011. Although two strategies, namely multimedia methods and explicit instruction in vocabulary instruction, as well as the question-answering strategy were found to be more frequently used than others, the authors noted these children my especially benefit from using the strategies recommended by NRP. The authors further explored the technology used in CBI and the effectiveness of using CBIs

in the learning of individuals participating in the studies. A very limited number of CBIs were either custom-developed or used in different studies. However, the authors found that the use of CBIs as an additional resource improved learning at an individual level. The researchers briefly mentioned that certain modalities made learning more interactive. The highlight of the study was determining the effectiveness of using CBIs for reading comprehension.

None of the reviews conducted investigated the use of modalities for language comprehension skills of children with ASD. Therefore, this review focuses on three main aspects related to language comprehension skills: 1) modalities used in different studies; 2) effectiveness of CBIs in which such modalities have been integrated; and 3) identifying potential modalities and CBIs for future studies.

2.5.2 Method

A specific process as defined by Kitchenham (2004) was followed to conduct this review. The process consists of the following steps.

2.5.2.1 Planning the review

To carry out the search in the selected databases and journals, the research objectives were defined followed by the formulation of research questions, search strategy and criteria; the inclusion criteria are explained in this section.

(a) ***Review objectives and research questions***

The systematic review began by identifying studies related to both components of language comprehension skills of children with ASD to determine the modalities used in those studies. However, due to a very limited number of studies available, the scope of our review was expanded by including components of decoding (phonemic awareness, phonics and oral reading fluency) skills as well. The expansion of our study area would reveal the

modalities used in those studies and modalities that could be investigated further in studies of language comprehension and decoding skills of children with ASD. Moreover, the findings also highlight the overall effectiveness of CBIs, including its effectiveness in the generalisation and maintenance of information. This review provides outcomes of the intervention and evaluates the certainty of evidence for each CBI. A total of six research questions were formulated to carry out a detailed review of the topic.

RQ1: Which modalities have been used for the language comprehension skills of children with ASD?

RQ2: Which modalities have been used for the decoding skills of children with ASD?

RQ3: Are CBIs found in RQ #1 and RQ #2 effective?

RQ4: Are CBIs effective in the generalisation of information?

RQ5: Are CBIs effective in terms of maintenance or retention of information over the period of time?

RQ6: Does the use of teacher and CBI together provide better results in the learning of children?

(b) ***Search strategy***

According to the guidelines given by (Kitchenham, 2004), once the research objectives are finalised and the research questions created, a formal searching strategy must be formulated so that all the empirical evidences related to the research objectives can be analysed. This plan involves defining the search space, including electronic databases and other attributes, as shown in Table 2.3. All the research papers shortlisted and discussed in this review are referred to as part of the primary study whereas this review itself is considered as the secondary study. During our search process, each primary source was also checked to identify references for additional relevant studies to be added to our review. In addition, a

hand search was also performed in the selected journals mentioned in the Table 2.3. Then, the inclusion criteria were checked against each study found in the results.

Table 2.3: Search characterisation

Electronic databases	ACM Digital Library EBSCO IEEE XPLORE SAGE ScienceDirect SpringerLink Google Scholar
Searched items	Journals
Search applied to	Full text
Languages	English only
Publication time frame	January 2000 to June 2015
Specific journals looked into	Autism, Focus of Autism and Other Developmental Disabilities, Journal of Autism and Developmental Disorders and Research in Autism Spectrum Disorders

(c) ***Search criteria***

The search criteria for the studies included in this review consist of two parts, S1 and S2. S1 is a substring made up of all the keywords associated with autism, such as autism, autistic and ASD. S2 is another substring of all the keywords related to modalities, such as modal, technology, game, virtual, brain, computer, tangible, video, haptic and gesture.

Boolean expressions S1 AND S2 were created to carry out the search. A sample search string based on the above-mentioned expression is: (autism OR autistic OR ASD) AND (modal OR technology OR game OR virtual OR brain OR computer OR tangible OR video OR haptic OR gesture). The first part of the search string, i.e. S, would reveal all the studies related to ASD, while the second part of the search string, i.e. S2 would reveal all the studies on CBIs for ASD and modalities used in each intervention. The search string was manually created for the individual databases and journals based on their respective functionalities. This has been treated as a process of learning and experimentation.

(d) ***Inclusion criteria***

The following criteria were used to determine which papers would be included in the review: (1) the study directly answers any one or more of the research questions; (2) is published in a peer-reviewed journal between 2000 and 2015; and (3) is written in English.

(e) ***Data Extraction and certainty level determination***

A set of guidelines related to the data extraction process was followed to identify relevant information from the primary studies. A form was created with the following attributes to record information from the studies as a part of the data extraction process. The attributes include: (i) title; (ii) authors and their details; (iii) journal; (iv) year of publication; (v) focus of the study; (vi) participants' information and their diagnosis; (vii) modalities used in the study; (viii) outcome of the CBI; and (ix) certainty level.

The outcome of CBI on learning and its impact on the generalisation and maintenance of language comprehension and decoding skills were summarized in several ways depending on the experimental design used in the studies. For studies that employed group designs or analysed data at the group level, standardized mean difference effect sizes were estimated from F-statistics or repeated measures data using meta-analysis. A meta-analyses was used because this method can provide more accurate effect size estimates (Lakens, 2013).

For all those studies using a single-subject research design (SSRD), the Non-overlap of All Pairs (NAP; Parker & Vannest, 2009) was calculated from the data presented in the graph. The literature on nonoverlap methods for SSRD has shown that the number of these methods have increased since the last decade, and the difference between these methods is so subtle that each method can be easily confused with another. Among all the methods, NAP produces the most precise calculation as it uses all data points. According to Parker and

Vannest (2009), NAP is interpreted as the percentage of all pairwise comparisons across Phases A and B; this shows the improvement across these phases, or the percentage of data which has improved across both phases.

NAP is conceptually described as a complete nonoverlap index, as it compares all individual data points ($n_A \times n_B$). It is calculated as the number of improvements or positive (Pos) pairs plus half of ties (.5 × Ties), divided by all pairs (Pairs): NAP = ([Pos + .5 × Ties] / Pairs) that directly generate output from the raw scores.

The guidelines followed to determine the certainty of evidence are based on the research by (Ramdoss, Mulloy, et al., 2011). It was evaluated by considering the results in light of the research design and other methodological details (R. Schlosser & Sigafoos, 2007). High certainty of evidence means that the likelihood is low that the effect will be different enough from what the research found that it might affect a decision. For each study, certainty of evidence was classified as either suggestive, preponderant, or conclusive, per Figure 2.2. This classification of certainty of evidence is adapted from the research by (N. L. Smith, 1981) and (Simeonsson & Bailey, 1991).

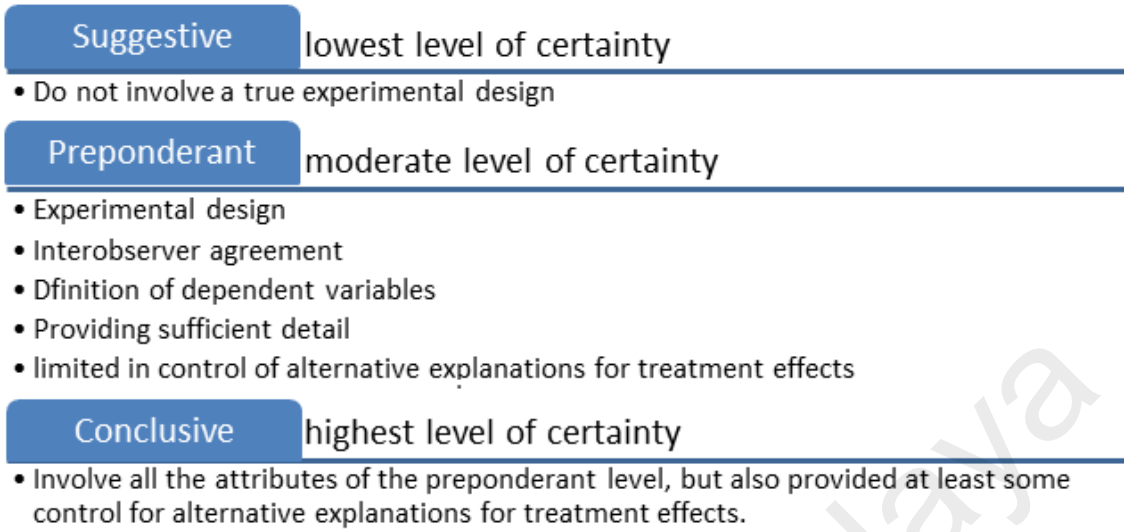

Figure 2.2: Certainty classification of evidence

From the three level of certainty, the lowest level was classified as suggestive evidence; a category within which studies may have utilised intervention-only or AB design, but did not involve a true experimental design (e.g., group design with random assignment, multiple baseline, or ABAB). The middle or second level of certainty was categorised as preponderant evidence which dictates five qualities for the studies within this category. The studies must: 1) utilise an experimental design. However, a demonstration of experimental control (e.g., divergence in data paths within an alternating treatment design) is also necessary for single case studies. 2) Report treatment fidelity measures and sufficient inter-observer agreement (i.e., a minimum of 20% of sessions with 80% or higher agreement or reliability). 3) Operationally define the dependent variables. 4) Provide adequate details to allow replication. And, 5) in certain ways be limited in their capability to control for alternative explanations for treatment effects. For example, the study may be classified into the preponderant level if concurrent interventions, such as CBI and teacher-implemented DTT, were targeting the same or related dependent variables, and no design feature controlled the influence of the non-CBI on the learning, generalisation and maintenance of language comprehension, and decoding skills-dependent variable. Finally, the highest level of certainty was classified as

conclusive. In this category, the studies had the same attributes as those in the preponderant level; however, a certain control for alternative explanations was provided for treatment gains (e.g., a multiple baseline across participants in which the introduction of the CBI was staggered and concurrent interventions were held constant, or a group design with appropriate blinding and randomization).

(f) ***Data analysis:***

This section describes how the data has been analysed for all the six research questions.

i Analysis in research question 1 and 2:

The text of entire manuscript especially the description of CBI was read in detail to determine all the modalities used in the CBI. The text was also analysed to identify if these modalities are used separately or a different subset of modalities are used in combination.

ii Analysis in research question 3:

The performance of children is measured at two levels: i) before using CBI; and ii) during and after using CBI. In the first level of assessment, data related to baseline measurement is considered, while aggregation of data in terms of intervention, generalisation, and maintenance is used at the second level of assessment.

The list of variables used for the analysis of data in studies include the following:

1. Performance of children during and after using CBI (dependent, ratio)
2. Performance of children before using CBI (dependent, ratio)
3. study (independent, nominal)

The levels of performances are compared using a form of multivariate. The analysis of variance is used to test the difference between the performances of children in the two above-mentioned levels. The test of difference between the two levels is conducted with two measurements, while the "study" is an independent variable; therefore, one-way MANOVA (multivariate analysis of variance) is used for the analysis. The one-way MANOVA is based on one categorical independent variable and two or more dependent variables (Huck & McLean, 1975). Although MANOVA is similar to ANOVA, the former is used with two or more dependent variables (Maceina, Bettoli, & DeVries, 1994).

A T-test is also performed to examine the H1 when the "study" is a covariant and only the following two variables are involved:

1. Performance of children during and after using CBI (dependent, ratio)
2. Performance of children before (without) using CBI (dependent, ratio)

The Kolmogorov-Smirnov test (Lilliefors, 1967) is also conducted to verify that the samples are from a known population that has a normal distribution. The Post hoc tests are also used to perform a separate comparison between pre-test and post-test analysis.

iii Analysis in research question 4:

The effectiveness of CBI in the generalisation of information is tested using a form of repeated measures. In the studies which contain generalisation tests, at-least three measurements are conducted i.e. during baseline, intervention and generalisation. There are a few studies like study (2), in which two tests of generalisation are conducted and considered to be generalisation 1 and generalisation 2, respectively. The results of generalisation 1 and 2

are aggregated as one generalisation variable to measure the effectiveness of systems in generalisation of information. The following two alternate hypotheses are tested:

H1 – There is a significant difference between the measures in baseline and generalisation:

The Analysis of Variance (ANOVA) is used to test the differences between the baseline and generalisation. The test of differences between measures is conducted repeatedly while other conditions such as participants who take part in the evaluation, i.e. children with ASD remain the same. Therefore, Split-plot ANOVA (SPANOVA) is used for the analysis. The SPANOVA is used to test the differences between two or more independent groups whilst subjecting participants are repeatedly measured (Huck & McLean, 1975). These assumptions must be taken into account when performing a SPANOVA test:

1) Each sample is independently and randomly selected.
2) The Kolmogorov-Smirnov test is conducted to determine whether the distribution of the response variables follows a normal distribution.
3) The population variances are equal for all responses at the group levels. The significance of results is checked through p-value at the level of 0.05.

SPANOVA is used to examine the performance rates of CBIs in different studies with normalised data.

H2 – There is a significant relation between the measures in intervention and generalisation.

Pearson Correlation Coefficient (CC) test is conducted to analyse the relationship between the performance of children in intervention and that of generalisation. This test is used to determine the type and degree of relationship of one quantitative variable with another

quantitative variable. CC is one of the factors used to determine the correlation between two variables (Croxton & Cowden, 1967) and SPSS is used for this purpose. The correlation coefficient, denoted by R-values, indicates how closely data in a scatterplot fall along a straight line. The closer the absolute value of R-value is to one, the closer the data is described by a linear equation. Data with values of R-value close to zero show little to no straight-line relationship.

iv Analysis in research question 5:

The effectiveness of CBI in the maintenance of information is tested using a form of repeated measures. For testing the maintenance, at least three measurements are conducted in the studies of baseline, intervention and maintenance. In two studies (Studies 9 and 10), the test of maintenance is conducted twice; therefore, both of them are considered maintenance 1 and maintenance 2. However, the results of both tests are aggregated when the tests are conducted to measure the effectiveness of systems in the maintenance of information over a period of time. The analysis is also conducted for studies 9 and 10 with two measurements of maintenance.

Similar to H2, SPANOVA is conducted to test the efficiency of CBI in maintenance.

v Analysis in research question 6:

SPANOVA analysis is conducted to determine which amongst the three different methods (teacher only, teacher and CBI, and CBI only) of teaching children with ASD is more effective. The performance of children has been measured in two steps, i.e. baseline and intervention. Post hoc tests are used to conduct a separate comparison between the mentioned teaching methods.

2.5.2.2 Conducting the review

In this section of the paper, the findings of the search carried out are presented for the following purposes.

(a) ***Study search and selection***

The basic selection criteria for the inclusion of primary studies in our review were based on the review of title, abstract and keywords. However, in certain cases, it was difficult to make a decision based on title, abstract and keywords. A simple solution to the problem was to read the introduction and conclusion sections of the full text; this action allowed us to select a research paper or delete it based on the inclusion criteria. A manual search of the list of references was also conducted in the included studies, and all those studies that met the above-mentioned inclusion criteria were incorporated in the review. Hence, a wider range of studies were gathered into this review.

(b) ***Validity controls***

i Tests for data analysis:

Five essential assumptions (45) were checked in factor analysis. The essential assumptions are as the following: 1) continues level of multi variables; 2) linear relation between all the variables; 3) sampling adequacy; 4) appropriate for data reduction; and 5) no significant outliers. Certain assumptions are also considered to perform ANOVA test: 1) each sample is an independent sample; 2) Normal distribution (the Kolmogorov-Smirnov test is conducted to verify that the sample comes from the known population as well as normal distribution.); and 3) At the group level, the population variances are equal responses. The significance of results is checked through P-value at the level of 0.05.

ii Inter-rater agreement

In order to ensure a high degree of reliability of the search procedure carried out, both authors of this research independently assessed each of the fourteen shortlisted studies according to the inclusion criteria. Only studies that met all the criteria were accepted while the rest were rejected. Based on the results, there was a unanimous decision on the studies shortlisted for this review.

2.5.3 Results

The year-wise distribution of all the shortlisted studies is shown in Figure 2.3, while a summary of these studies is presented in Table 2.4. The first seven studies are related to language comprehension skills, whereas, the remaining seven are related to decoding skills. Column 1 shows the study number which will be used during the discussion of research questions 3, 4, 5 and 6; the study numbers will be represented in the brackets and study (6) or studies (3, 5, and 6) are two examples of the same. Colum 2 shows the citation of each study, while the focus of each study is mentioned in Column 3. Column 4 presents information about the participants involved in the study, and all the modalities used in CBIs are shown in Column 5. Column 6 indicates the outcomes of using CBI, while the certainty level of study is described in Column 7.

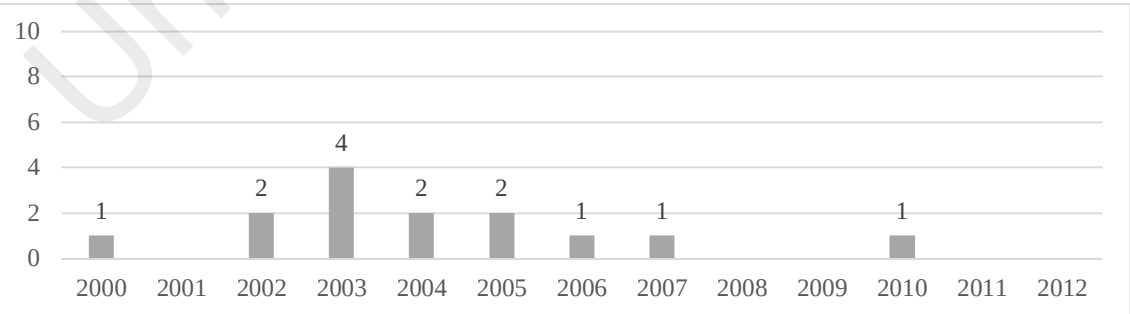

Figure 2.3: Publication years of shortlisted studies

Table 2.4: Shortlisted studies

Study #	Reference#	Focus of study	Participants	Modalities[#]	Outcome	Certainty Levels
Language comprehension skills:						
1	Massaro and Bosseler (2006)	Receptive identification of pictures and vocabulary	5 children (male: 4, female: 1) with mild to moderate autism Ages: 8–13 years	Basic and virtual/animated character	Results: Performance of children was better in post-test than pre-test. Results were statistically significant when only animated face was used. Results were statistically insignificant when both animated face and voice were used together. The overall average of correct receptive responses pooled across lessons increased with standardized mean difference effect size = 3.694.	Preponderant- A group experimental design across four lessons; two with the face (F1 and F2) and two without the face (N1 and N2) is used. The repeated measurement is conducted and dependent variables are defined. The study has the attributes of preponderant certainty evidence.
2	Bosseler and	Receptive identification	9 children (male:	Basic and	Results: Children	Conclusive- This study has a

	Massaro (2003)	of pictures and vocabulary	8, female: 1) with autism, AD: 2 children with MR were recruited but 6 took part in the evaluation Ages: 7–13 years	virtual/animated character	successfully identified more correct words b/w pretests and post-tests, and during re-assessment; this indicates they learnt and retained words. Results were statistically significant. Mix mode, single and multiple case study design. The analysis of results show that in experiment 1, the number of vocabulary words has been increased with standardized mean difference effect size = 0.710 and in experiment 2 the number of vocabulary words increased with standardized mean difference effect size = 2.884.	group experimental design to examine whether children with autism could learn new vocabulary. A repeated measurement is conducted: an initial measurement test, training and testing, and a reassessment test after 30 days. The study has the attributes of preponderant evidence. Moreover, the second experiment provides a control for alternative explanations for treatment effects so, it has a conclusive evidence.
3	Basil and Reyes (2003)	Sentence construction, reading of letters,	Total: 6 children (male: 3, female:	Basic	Results: Students' showed significant	Preponderant- The study has used a group experimental

		syllables, words, and sentences, and reading comprehension	3) 2 children (Boy: 1, Girl: 1) with DS 2 children (Boy: 1, Girl: 1) with autism 1 boy with MMD 1 girl with ID Ages: 8–16 years		improvement in sentence production. Results were statistically significant b/w initial & third assessment and b/w initial & final assessment. Results were insignificant b/w initial & second assessment.	design. Repeated measurement, involving baseline and intervention, is conducted on literacy skills of students. That matches with the first attribute of preponderant evidence. It does not provide any control for alternative explanations for treatment gains therefore, it has not a conclusive evidence.
4	O. E. Hetzroni and Shalem (2005)	Matching word to sample	6 children (male: 3, female: 3) with autism and moderate MR Ages: 8–13 years	Basic	*Results:* Correct matches between text and food items improved for all participants NAP = 90.3%, values ranged from 79% to 97.9%. All participants were able to maintain the knowledge over time. Most of the participants were able to generalise the knowledge to daily activities within the classroom.	Conclusive- A multiple-probe design across participants is used with two sets of three students in one school setting. In this experimental design, comparisons were made for each participant between baseline and intervention, across three participants, with two replications. The study involves group experimental design with repeated measurement so it has not a suggestive certainty. Moreover, the researcher observed all intervention sessions to ensure computer program ran

						as designed so it can be involved in conclusive certainty evidence category.
5	O.E. Hetzroni and Tannous (2004)	Communication function	5 children with autism Ages: 8–13 years	Basic	Results: all children produced fewer sentences with delayed and irrelevant speech. Most of the children engaged in fewer sentences involving immediate echolalia and increased the number of communication intentions and the amount of relevant speech they produced. Generalisation: children were able to transfer their knowledge to the natural classroom environment.	Preponderant- In this study, a multiple-baseline design across three settings has been implemented. Three computer-based training settings have been used to investigate transfer to the natural classroom setting. The study involves multiple baselines so it has not a suggestive certainty. Moreover, no control variable is considered so could not be in conclusive certainty evidence category.
6	Moore and Calvert (2000)	Identification of vocabulary	14 children (male: 12, female: 2) with autism Ages: 3–6 years	Basic	Results: Students paid more attention, learnt more and were motivated to interact with computers rather than teachers. Results were statistically significant.	Preponderant; details regarding the type of hardware and piloted software developed for this study were not provided in sufficient detail to enable replication.

7	Whalen et al. (2010)	Receptive language, expressive vocabulary, and academic/cognitive skills	47 students (22 in treatment group, 25 in control group), with mild to moderate autism Ages: 3–6 years	Basic and virtual/animated character	*Results:* Children showed significant improvement in language between pre-test and post-test. Results were statistically significant.	Preponderant; seven students in treatment group did not master a lesson and thus did not complete a post-test. Exclusion of students from measurement positively biased results. A between subject, randomized (by classroom) design was implemented. However there is not any control for alternative explanations for treatment gains.
Decoding skills:						
8	Coleman-Martin, Heller, Cihak, and Irvine (2005)	Word identification using the Nonverbal Reading Approach (NRA)	3 female with autism AD: 1 had CP, and 1 had brain injury from a stroke Ages: 11–16 years	Basic	Results: Results show that NRA can be delivered through CBI. Teacher+CBI had better results than CBI or teacher alone and CBI had better results than teacher. Number of vocabulary words increased (NAP = 100%). Person implemented instruction also associated with a NAP value of 100%.	Conclusive- A multiple-conditions design with drop-down baselines is used to investigate the effectiveness of teaching word identification using the NRA across three conditions: (a) teacher instruction only, (b) teacher and CAI, and (c) CAI only. Multiple baselines has been conducted and during each baseline, words were assessed across each student for three sessions. Control for alternative explanations for treatment gains is

						provided.
9	Delano (2007)	Essay writing using self-regulated strategy development (SRSD) through video modelling	3 male adolescents with autism Ages: 14–18 years	Basic and video model	*Results:* students demonstrated gains in the number of words written and number of functional essay elements. Maintenance of treatment effects varied across participants.	Conclusive- A multiple baseline design across responses (words written and functional essay elements) was used to assess the effects of the self-regulated strategy development intervention package that sequentially targeted words written and functional essay elements and also control for alternative explanations for treatment effects are involved.
10	O. E. Hetzroni, Rubin, and Konkol (2002)	Sight word reading	3 female with RS Ages: 8–10 years	Basic and video model	*Results:* participants demonstrated a steady learning curve across symbol sets and a partial retention during maintenance.	Suggestive – single baseline, intervention, and maintenance is conducted across the four sets for Ann.
11	Kinney, Vedora, and Stromer (2003)	Spelling	1 female with autism Ages: N/A	Basic and video model	*Results:* Phase 1: child rapidly learned to spell three five-word sets based on pictures and dictation. Phase 2: child learned to spell four novel words and arranged into a teaching matrix of three beginning consonants and three word endings.	Suggestive-It has analysed the effects of a video-based intervention across three five word sets. However, did not involve a true experimental design such as group design with random assignment or multiple baseline.

					Phases 3 and 4: child learned to spell subsets of four 3x3 matrices, then immediately proved capable of spelling the remaining words in each matrix. Generalisation and maintenance tests at home and school throughout the study generalisation and maintenance tests at home and school throughout the study	
12	Linda C Mechling and Gast (2003)	Sight word reading	3 students (male: 2, female: 1) with mild to moderate ID Ages: 12-18 years	Basic	*Results:* Participants were able to match associated words on a grocery list with words on a grocery store aisle sign. Participants generalised reading of the associated word pairs and location of the grocery items in the store	Conclusive- A multiple probe design across three job tasks and replicated across three students has been used to evaluate effectiveness of CBVI to teach job skills. Multiple steps of each job task were individually taught to each student using constant time delay and the computer-based program that provides the control for alternative explanations of treatment effects.
13	(L. C. Mechling & Ortega-Hurndon, 2007)	Multiple step, job tasks in a generalised settings	3 students (male: 2, female: 1) AD: All with	Basic and video model	*Results:* Instruction given through CBI resulted in 96.5%	Conclusive-A multiple probe design across three sets of associated word pairs and

			moderate ID, 1 male with ADHD Ages: 21–22 years		correct performance of steps across the job tasks Participants generalised and maintained multi-step job tasks.	replicated across three students. The study evaluate the effectiveness of the multimedia program along with control for alternative explanations of treatment effects.
14	R. W. Schlosser and Blischak (2004)	Spelling	4 male children with autism Ages: 8–12 years	Basic	*Results:* All 4 children reached criterion across conditions. Although 3 children reached criterion first with print or speech–print feedback, 1 child was most efficient with speech–print followed by speech feedback. Generalisation: 2 failed to generalise, while all children maintain spellings learned over the period of time.	Preponderant- An adapted alternating treatments design is used. Dependent measures used to determine the effectiveness and efficiency of each condition included (a) percentage of correctly spelled words, (b) percentage of correct letter sequences, and (c) number of sessions to criterion.

2.5.4 Discussion

In this section, the results of the systematic review are analysed in an attempt to answer all the research questions presented in Section 2.5.2.1(a).

2.5.4.1 Research question 1:

Among the set of seven studies related to language comprehension skills, it was found that a subset of modalities, i.e. text, graphics, audio and video were used in most of the studies; therefore, this subset is termed basic modalities, as shown in Column 5 of Table 2. In addition to basic modalities, virtual/animated characters were also used in the studies. These characters are used for multimodal interactions between a child and the CBI. Among most of these characters, both face and lip movements are synchronised to make the characters appear like a human being. These characters have varying functionalities: ability to walk, talk, use different gestures and perform different tasks, and so on. The studies that employed these modalities are briefly described below.

In the study by Basil and Reyes (2003), students took part in the learning activities using a CBI called “Delta Message”, followed by a test task. During learning activities, they were shown a set of words and asked to construct a sentence by making use of the whole-word selection process. Once they had completed a sentence by dragging whole words to any place in the sentence they wanted, the words were articulated in the form of digital speech; at the same time, they also saw the animation of the sentence they had constructed. However, during the test task, the above process occurred in the reverse order. That is, students were asked to construct appropriate sentences that described actions shown in the image. Results showed improvements in the production of the

sentences targeted in the program, and the ability to synthesise and spell words that were not targeted in the program.

Two studies by Bosseler and Massaro (2003), as well as one by Massaro and Bosseler (2006), used a 3D animated character called Baldi as a mode of communication to teach vocabulary to children with autism. Children were given verbal instructions and shown a set of images for them to select the correct image. In one of their experiments, they only played the audio of human voice; in another experiment, they showed Baldi as well. The authors found children had better interactions and learnt more when Baldi was shown. The value of visible speech, emotion, and intention in face-to-face communication was the primary motivation in the development of Baldi, a three-dimensional computer-animated talking head. Baldi provides realistic visible speech that is almost as accurate as a natural speaker (Cohen, Walker, & Massaro, 1996; Massaro, 1998). The quality and intelligibility of Baldi's visible speech was repeatedly modified and evaluated to accurately simulate naturally talking humans (Massaro, 1998). Baldi's visible speech can be appropriately aligned with either synthesised or natural auditory speech. Baldi also has teeth, tongue, and a palate to simulate the inside of the mouth, and the tongue movements are trained to mimic natural tongue movements.

Research by O.E. Hetzroni and Tannous (2004) investigated enhancement of communication functions among children with autism. Activities of daily life focused on in the program included play, food, and hygiene. Variables investigated included delayed echolalia, immediate echolalia, irrelevant speech, relevant speech, and communicative initiations. Results showed that all children produced fewer sentences with delayed and irrelevant speech; most of the children who produced fewer sentences

had immediate echolalia, and increased number of communicative initiations, and an increased amount of relevant speech. These children were able to generalise knowledge to a natural classroom environment. The authors had mentioned that allowing children to practise in a controlled and structured setting that provided them with opportunities to interact in the activities related to play, food, and hygiene allowed them to generalise the material learnt and then transfer their knowledge to the natural classroom environment.

The study by O. E. Hetzroni and Shalem (2005) covered teaching of orthographic symbols. The authors used the seven-step fading procedure to teach identification of words from commercially available logos that depicted food items. The results showed that children were able to identify orthographic symbols and maintained performance over the set time frame. These children were also able to generalise it to daily activities within the class.

The authors in Moore and Calvert (2000) compared attention following, motivation and learning of words by children using CBI with behavioural programmes in which a teacher was involved. This CBI made use of basic modalities. The authors found that children were more attentive and motivated when using CBI; they learnt more words and increased their vocabulary and reading comprehension ability.

The authors in Whalen et al. (2010) used an online system known as 'TeachTown: Basics' as a CBI to improve vocabulary apart from cognitive thinking and social communication of children with autism. Students were given verbal prompts by the program and asked to respond to a question based on 3 to 8 choices displayed. The correct answer was reinforced with verbal praise and a short animation. The authors found that CBI played an effective role in teaching various skills to children with autism

and all the students showed improvement in knowledge when results were compared between the pre-tests and the post-tests. Furthermore, students using the CBI for a longer time showed more improvements than the students who used it for a shorter time. A summary of modalities and CBIs used is shown in Figure 2.4 and represents the action modalities from Figure 2.1.

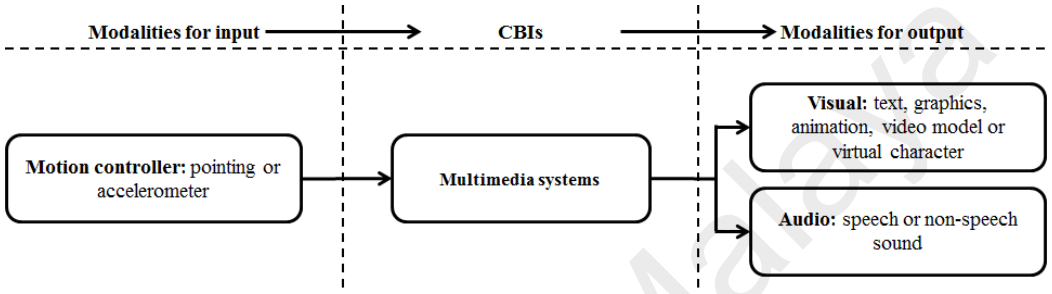

Figure 2.4: Modalities used in the CBIs for language comprehension skills of children with ASD

2.5.4.2 Research question 2:

Among the set of seven studies related to decoding skills, all were found to have used basic modalities as shown in Column 6 of Table 2. There were a few studies which had also used video model in which desire behaviours were learned by watching the video demonstrations of some models and then the user was asked to imitate the same behaviour. The studies which had used these modalities are briefly described below.

Coleman-Martin et al. (2005) conducted a study to determine if computer-assisted instruction (CAI) could be beneficial to promote word identification using the Nonverbal Reading Approach (NRA). The study was conducted in three conditions: (1) teacher only; (2) both teacher and CAI; and (3) CAI only. In CAI, words were presented using Microsoft PowerPoint where each slide had a visual and audio component. Results indicated that the NRA could be effectively delivered through computer-assisted instruction, thus freeing up teachers' time and providing students with the ability to

practise decoding and word identification independently. It was also found that most of the students took longer time to learn the words in the teacher-only condition.

O. E. Hetzroni et al. (2002) designed a study to investigate whether the use of assistive technology by girls with Rett syndrome could help them to identify symbols. The items were shown in the form of pictures together with a voice asking to select the right option. Items were randomly placed on the screen to prevent position bias. One or two items were used as foils with one correct item, which was to be identified by the student. If a correct selection was made, the symbol re-appeared with a happy smiley face in the centre of the screen and a picture of the referent. If an incorrect selection was made, the correct response appeared with a sad face in the centre of the screen. Results showed a steady learning curve of girls in four sets of different symbols and a partial retention of knowledge during the maintenance phase.

Linda C Mechling and Gast (2003) and L. C. Mechling, Gast, and Langone (2002) conducted a study to evaluate whether multi-media instruction could be used to teach students with intellectual disabilities to locate grocery items by reading words on aisle signs that were associated with the target item word. Multi-media instruction was provided using text, photographs, and video recordings depicting the target grocery items and the associated words on aisle signs. Results indicated that the multi-media program was a very effective way to teach generalised reading of the associated word pairs and location of the grocery items in the store.

Delano (2007) conducted an exploratory study to evaluate the effect of self-regulated strategy development (SRSD) instruction on the rate of words written and rate of functional essay elements. The results showed that using SSRD, each student

demonstrated gains in the number of words written and number of functional essay elements.

A study was conducted by R. W. Schlosser and Blischak (2004) to evaluate the effect of speech and print feedback on spelling performance. A speech-generating device was used in the study under 3 feedback conditions: (1) auditory–visual condition in which they received both speech and printed feedback; (2) only auditory; and (3) only visual conditions, in which only 1 type of feedback was provided. The authors concluded two things based on their evaluation: (1) children who demonstrated visual learning could spell words efficiently if they received feedback in the form of printed text on screen; (2) children who were comfortable in using audio could spell words more efficiently if they were provided with feedback in the form of speech.

A study by Kinney et al. (2003) examined the use of computer video models and video rewards to teach generative spelling to a child with ASD. This study was conducted in 4 different phases. In Phase 1, a video model of the teacher writing target words was shown to the child. In Phase 2, the child learned to spell four novel words and arranged them into a 3-by-3 matrix having a combination of beginning consonants and word endings. In Phases 3 and 4, the child learned to spell subsets of four three-by-three matrices. Results of the study showed that the child enthusiastically took part, learning a substantial number of written spelling and maintaining most of the words. The child was quite successful in the generalisation and maintenance tests carried out at home and the school during the study. A summary of the modalities and CBIs used is shown in Fig. 4. The modalities are classified and displayed according to their use in the system, i.e. either for input or output. All the modalities related to each other are grouped together and shown in a separate rounded rectangle where each group is given

a name representing the gist of modalities in it. For instance, output modalities including text, graphics, animation, video models, and virtual characters are grouped together with the name of 'visual.' The centre part of the figure shows the types of CBIs that have been developed. In comparison with the modalities shown in Figure 2.5, it can be seen that the use of different modalities like video model or speech among others has increased. The modalities in this figure represent both the sensing and action from Figure 2.1.

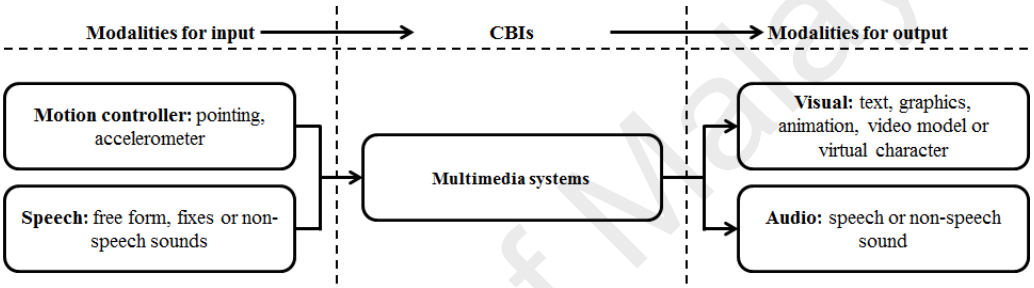

Figure 2.5: Modalities used in the CBIs for decoding skills of children with ASD

2.5.4.3 Research question 3:

Among language comprehension skills, (N=6 out of 7) 84% of the studies revealed positive results, whereas on decoding skills, (N=7 out of 7) 100% of the studies reported positive findings on using CBIs. One study (5) on language comprehension showed mixed results for the participants i.e. a few of the participants showed improvement while the remaining did not exhibit any improvement.

The estimated marginal means demonstrates that the CBIs improved children's performance in all the studies except study (5), as shown in Figure 2.6.

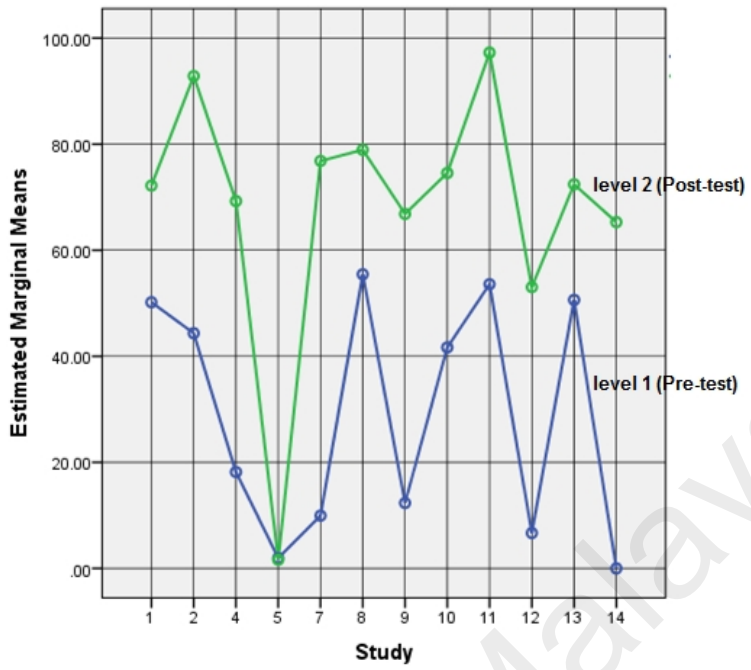

Figure 2.6: Performance of children before and after using CBI systems

Table B.1 of Appendix B shows the performance of children before and after using CBIs for each study. N is the number of children and mean is the average of their performance. In study (5), the performance has some reduction from 1.94 to 1.63 while the two studies (7 and 14) have a significant improvement.

The results of the one-way MANOVA test (Table B.2 of Appendix B) shows that there is a significant difference in the performance of children between the three levels of measurement (see Section 2.5.2.1(f)ii): [$F(1, 80)= 882.290$, $p< .05$]. Therefore, the null hypothesis is rejected and CBI is statistically effective in the performance of children. There are significant differences among the studies in terms of improvement in the performance of children: [$F(11, 80)= 33.072$, $p< .05$]. This shows that the use of CBI has a significant effect in the performance of children.

The results of post hoc tests show homogeneity among the studies; therefore, studies in the same subset are similar in terms performance of participants using CBI (Table B.3 of Appendix B). study (5) does not share the homogeny of any other studies.

The T-test results also reject the null hypothesis and shows the overall efficiency of CBI: [F(1, 148)= 39.664, p< .05] (Table B.4 of Appendix B).

2.5.4.4 Research question 4:

In studies (2, 9 and 14), the children in the intervention step have better performance than that of generalisation. In studies (4, 11, 12 and 13), the CBIs provide an efficient generalisation (Figure 2.7). Four studies, i.e. studies (5, 7, 8 and 9), that had performed tests of generalisation but the authors of these studies had not presented the results; hence, it is not possible to analyse the performance of CBIs used in those studies. It can be seen that the performance of children in study (12) during the baseline is almost zero. This is because speech output was turned off and the display of the system was also covered, such that the child could not learn from the speech and printed feedback while the test in the baseline was being conducted. Further, instead of providing corrective feedback, they were only provided with the intermittent spoken praise like "You are doing fine".

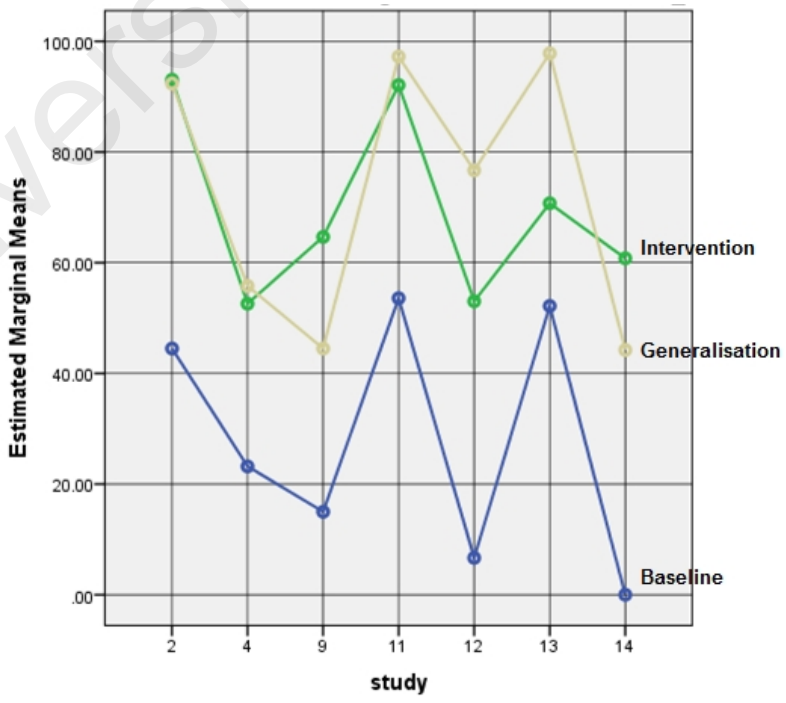

Figure 2.7: Generalisation of information through using CBIs

In study (12), there is a maximum difference between the performance of the baseline and the generalisation. In study (13), there is a maximum difference between the performance of intervention and that of generalisation. Therefore, the systems in Studies (12 and 13) are more efficient than the others in terms of generalisation of information by the users (Table B.5 of Appendix B).

In study (12), the authors provided instructions to the children using simulated multi-media program with text, photographs, and video recordings so that they could locate grocery items by reading words on the aisle signs that were associated with the target item word. Although the results showed that children were able to generalise the grocery from one store to another, the authors mentioned that this generalisation of item was limited to a particular brand of item that was taught from the program. If shown the same product of another brand, they were unable to identify whether the item was the same or different.

The authors of study (13) made use of subjective viewpoints (Norman, Collins, & Schuster, 2001) to create video segments by moving the camera as if it were the student who moved around and performed the tasks. The benefit of using subjective views is to facilitate the student in seeing how the actual environment would look like and how they would perform each step to accomplish the day-to-day tasks assigned to them.

As shown in Table B.6 of Appendix B, the SPANOVA results show that there is a significant difference in the performance of children between the baseline and generalisation measures: [$F(1, 37) = 53.239$, $p < .05$]. Therefore, the null hypothesis is rejected and CBI is statistically effective in generalisation of information. Moreover, there is a significant difference between study * measures: [$F(6, 37) = 601.147$, $p < .05$].

Therefore, the implementation of CBI method in the studies has a direct impact on the efficiency of generalisation.

The results of tests for subject effects indicate that the studies have a statistically significant effect on the dependent variable, i.e. "performance of children": [$F(11, 80)= 34.631$, $p< .05$] (Table B.7 of Appendix B).

Table B.8 of Appendix B shows that the percentage of generalisation is higher compared with that of the intervention; therefore, the use CBI increases the generalisation of information

The results of CC test as shown in Figure 2.8 indicate that there is no statistically significant relation between the baseline and intervention as well as between the baseline and generalisation. It indicates that the CBI systems have different effects on learning and generalisation. However, there is a significant and linear relation between intervention and generalisation. Therefore, the CBI systems have the same effect and success rates in terms of learning process and generalisation.

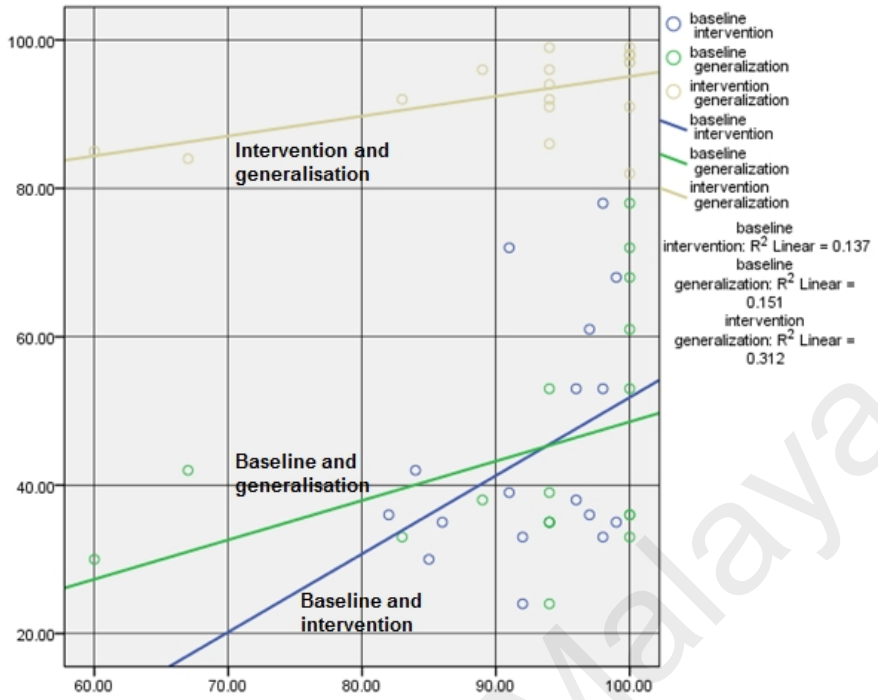

Figure 2.8: Correlation coefficient (CC) between baseline, intervention and generalisation

2.5.4.5 Research question 5:

One of the seven studies on language comprehension skills and four (N=4 out of 7) of the studies on decoding skills covered evaluation of maintenance of skill after the withdrawal of intervention between 1 week and 10 months. All of them reported positive findings. Two studies (8 and 9) started maintenance just after a week of withdrawal from intervention; one study (10) carried out maintenance after 4 weeks and again after 10 months. Studies that have maintenance generally produce stronger intervention results and have long-lasting effects compared to studies without maintenance.

Table B.9 of Appendix B shows the means of measurements at the baseline, intervention and maintenance. Study (14) has provided the maximum maintenance ability to children while study (8) with the maximum baseline has a moderate maintenance; the quality of systems has a high impact on maintenance. From study (14),

it can be seen the performance of children with interest in specific types of feedback (print, speech or both print and speech) continues to improve in the maintenance. If the child is verbal, the verbal feedback helps him in the learning of contents, and s/he performs better during and after the withdrawal of intervention. The same trend can also be seen for the feedback based on print only as well as speech and print.

In all studies, the measurement of maintenance is higher than those of the baseline and intervention; this shows that CBIs are effective and allow children to retain information for a longer period of time (Figure 2.9).

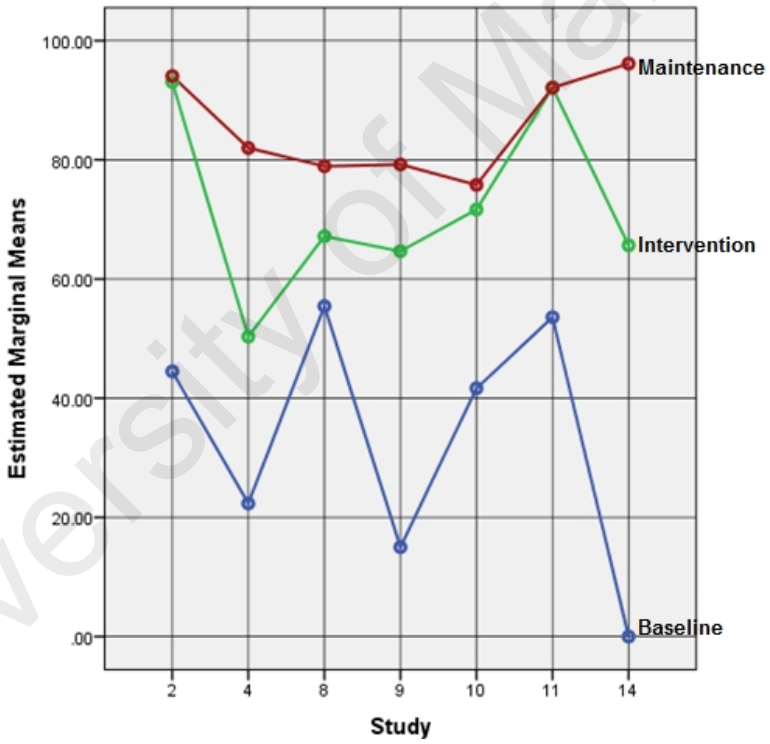

Figure 2.9: Maintenance of information through CBI

The results of SPANOVA assumptions for normality, homogeneity of covariance, and linearity are satisfactory. The result of Sphericity Mauchly is significant; therefore, adjustment of the df value is required by referring to the Huynh-Feldt value. The results of Huynh-Feldt show the significant differences between the baseline, intervention and maintenance (Table B.10 of Appendix B).

After the df adjustment, the SPANOVA (within-subjects factor) results (see Table B.11 of Appendix B) show the main effect of the multimodal system on learning, which is the overall multimodal effect. There is a main effect for the repeated variable MEASURE, [F(1, 38)=25.381 p< .05]; and interaction effect for MEASURE*STUDY, [F(6, 38)= 3.214, p< .05].

The null hypothesis is rejected and the CBI is significantly effective in improving the learning performance of the children.

The results of SPANOVA (tests between subject effects) (Table B.12 of Appendix B) show that there is a significant difference between studies where [F (6, 38) = 18.517, p< .05]. Therefore, the implementation method of CBI, which is adapted in the studies, has a direct impact on the efficiency of maintenance.

For Studies 9 and 10, there are two measurements for maintenance: maintenance 1 and maintenance 2. Study 9 shows better performance until it reaches maintenance 1 and Study 10 is more successful in maintenance 2 (Figure 2.10).

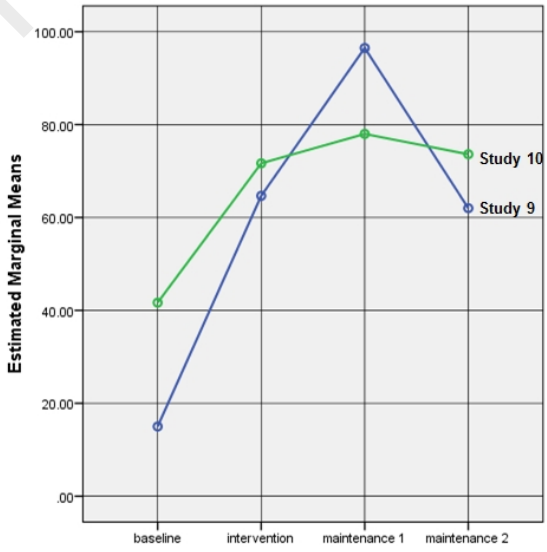

Figure 2.10: Two step measurement of maintenance

As shown in Table B.13 of Appendix B, the results show that the performance of children is reduced for maintenance 2 in both studies; however, the reduction in Study 9 is less than that of Study 10.

2.5.4.6 Research question 6:

Table B.14 of Appendix B shows that the use of "Teacher and CBI" together provided better results for the learning of children compared with that of the CBI or teacher only, while the CBI only method has provided better results than that of teacher only.

The results of SPANOVA show that there is a significant difference between teacher and "Teacher and CBI" method in the learning quality: [$F(2,57)=10.113$, $p<.05$]. (Table B.15 of Appendix B) as shown in Figure 2.11 "Teacher and CBI" is the most effective method of learning, followed by CBI only and teacher only. It can be seen that "Teacher only" is the weakest of the three types of teaching methods used in the studies to teach these children.

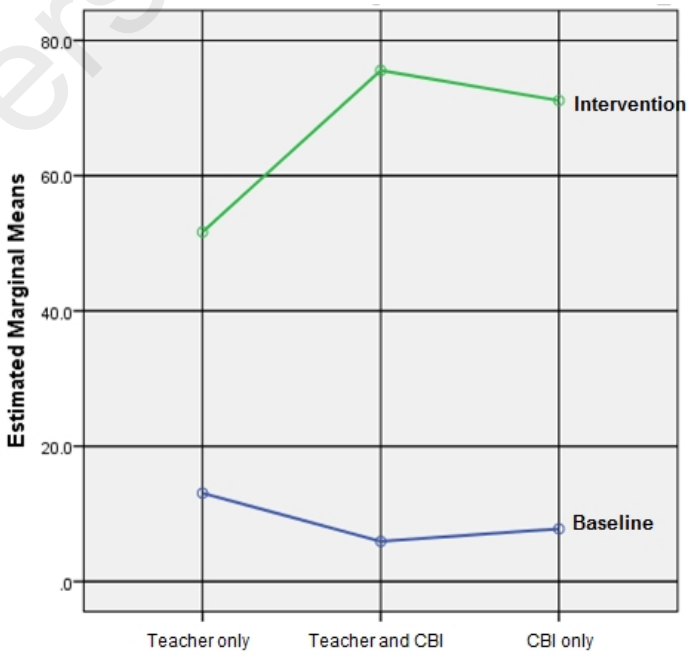

Figure 2.11: Learning methods comparison

The results (Table B.16 of Appendix B) of the post hoc test show that the "Teacher and CBI" method is more effective than "CBI only"; however, there is no significant difference between "Teacher and CBI" and "CBI only", where p-value is 0.984. The "CBI only" is more effective than "teacher only", but there is no significant difference between "CBI only" and "teacher only" where p-value is 0.119.

2.5.4.7 Certainty of evidence

The certainty of evidence for intervention effects was rated as proponents for six studies (Basil & Reyes, 2003; O.E. Hetzroni & Tannous, 2004; Massaro & Bosseler, 2006; Moore & Calvert, 2000; R. W. Schlosser & Blischak, 2004; Whalen et al., 2010). Preponderant ratings were assigned due to these studies' inability to control for alternative explanations for treatment effects and/or reporting of insufficient detail to enable replication. Six studies were rated as providing conclusive level of certainty (Bosseler & Massaro, 2003; Coleman-Martin et al., 2005; Delano, 2007; O. E. Hetzroni & Shalem, 2005; Linda C Mechling & Gast, 2003; L. C. Mechling & Ortega-Hurndon, 2007). For the remaining two studies (O. E. Hetzroni et al., 2002; Kinney et al., 2003), the certainty of evidence for intervention effects was judged to be suggestive. Table 2.4 provides specific reasoning behind each of the ratings given to each study.

2.5.4.8 Limitations of the review

In this review, only published studies were considered; however, studies presented in conferences and workshops may also provide some useful input to the researchers. This study is an attempt to explore six specific research questions, rather than a comprehensive review of the subject matter.

2.5.5 Summary

This systematic review began by setting the publication period from January 2000 to June 2015 for the selection of relevant studies to answer six research questions providing insight into the modalities used in the CBIs developed to support children in the learning of language comprehension and decoding skills. It also provides details about the effectiveness of these CBIs in terms of learning, generalisation and maintenance of information. Following are the key findings from the SLR:

1. A subset of modalities, i.e. text, graphics, audio and video were used in most of the studies of language comprehension skills.
2. Virtual/animated characters were also used in the studies of language comprehension skills for multimodal interactions between a child and the CBI.
3. A video model was used in some of the studies of text comprehension skills.
4. The studies across the language comprehension skills have reported positive findings on using CBIs and it supported in the generalisation and maintenance of skills over the period of time.
5. The use of "Teacher and CBI" together provided better results in the learning of children compared with that of the CBI or teacher only; similarly, the CBI only method provided better results than that of the teacher only.
6. Serious games and virtual learning environments (VLEs) are under-utilised to provide intervention of vocabulary learning to these children.

2.6 Serious game

The children with ASD can retain information for longer time duration if the information is presented visually to them. Serious game is one of the interactive ways which allow these children to remain engaged in a learning process and improve their

skills. In this section, the usefulness of serious games is discussed and the serious game developed for children with ASD is reviewed.

According to Abt (1987), serious games have an explicit purpose of providing an education of some skills to the users and should not played solely for the purpose of entertainment or amusement. From the literature review, it is apparent that there is no single acceptable definition of serious games. From one perspective, the use of the word 'serious' means embedding some pedagogical element into the games (Iuppa & Borst, 2006), whereas, from another perspective, 'serious' refers to the purpose of these games (Zyda, 2005). Susi, Johannesson, and Backlund (2007) have suggested that serious games are instantiation of game-based technology which are used to solve problems in real life which are either too critical or too expensive; for example, education, air field, healthcare, sales and marketing, and army. One of the important characteristics of serious games is that their definitive objective is to provide education. Sawyer (2007), in "Ten Myths about Serious Games", noted that learning through serious games is not as fun and entertaining as it is by using any typical games; however, serious games are developed keeping one fact in mind; that their primary purpose is to provide learning to their user and fun may be a part of it. Most importantly, one can even learn without having fun and yet playing games at the same time.

Serious games can exploit rich features of gaming to provide interactive platform to the users while keeping them engaged in the learning and having fun. Gee (2007) has identified that serious games:

- Encourage active rather than passive learning
- Encourage the learner to take risks, thus allowing the learner to make mistakes without being embarrassed

- Allow for mutual collaboration (networking) in order to solve a problem
- Encourage intrinsic learning because, compared to traditional methods, games are more engaging and more interesting
- Do not bore the learner with lots of practices; the use of humour, fun, and challenge will make the learning experience more memorable
- Let the learner learn together with sound, interaction, images and text; not just words.

The community of game developers, educational practitioners and the developers of serious games at "Serious games jam"[1] had a huge debate on the correct definition of "serious games." The emphasis of the participants during the debate was that fun is not to be given consideration in serious games, whereas some of the other elements of a game which include satisfaction, motivation, relevancy and engagement of user should be given importance over fun. This discussion is also supported by (Rooney, O'Rourke, Burke, MacNamee, & Igbrude, 2009; Westera, Nadolski, Hummel, & Wopereis, 2008) that fun should not be the primary motive in designing serious games. Kiili (2005) also emphasized that fun should not be a primary factor in the design of serious games, but, in order to achieve an interactive and meaningful learning experience, there is a need to integrate educational theories of game design in serious games.

In this thesis, a serious game is defined as "an integrated and interactive learning environment to achieve learning objective than just pure entertainment" based on the definition of serious games by (Yusoff, 2010).

[1] http://playgen.com/serious-games-jam/

The main purpose behind using this approach is that learners are not only motivated because of the game engagement features but also because of the integration of some pedagogical elements in the game. These elements are very much needed to meet the learning objectives of the game. In this way, a serious game will not be the same as of a typical game which sole purpose is to provide entertainment and fun; instead, these gaming features will be used as a driving force to achieve overall learning objectives of the game. Serious games can be similar to simulation games which mirror the real world scenario in a virtual word, it may not be purely designed for fun but still, it is not boring.

The use of serious games for children with autism has increased since the last decade. Researchers have started using the potentials of serious games to provide training of various skills including reading, writing, social, communication etc. The serious games for autism have been developed for two major purposes: the first is for therapy and the second as a part of education (including learning and training).

A review of serious games developed for children with ASD was carried out with the intention to identify behaviours that have been targeted in the games, technologies that have been used in these games and the outcomes of using them. Research articles were searched in six databases: 1) IEEE, 2) ACM, 3) ScienceDirect, 4) Springer, 5) Sage, and 6) Google Scholar. A set of keywords were used with different combinations to locate articles in the mentioned databases. The set of keywords include: (“Serious game” OR “game” OR “game-based”) AND (“autism” OR “autism spectrum disorder” OR “ASD”). Based on the search results, 23 studies were shortlisted for further investigations. The summary of these studies is presented in Table 2.5 according to education-related and therapy-related serious games.

Table 2.5: Serious games for children with ASD

Citation	Participants	Target behaviour	Technology used	Results
Education-related serious games:				
Ben-Sasson, Lamash, and Gal (2013)	12 boys with HFASD ages 8–11 years	Social behaviour	Multi-user tabletop device	Positive
Dillon and Underwood (2012)	10 (9 male, 1 female) with HFASD and 10 (4 male, 6 female) TD	Story telling	GUI-based application	Positive
Jain, Tamersoy, Zhang, Aggarwal, and Orvalho (2012)	9: 5 – 12 years old 6 with HFD, 2 with LFD and 1 SFD	Recognition of facial expressions	Xbox 360	Not available
Frutos, Bustos, Zapirain, and Zorrilla (2011)	Not available	Verbal communication skills	GUI-based application	Not available
Hassan et al. (2011)	Not available	Understanding the concept of money and the use of money	GUI-based application	Not available
Finkelstein, Nickel, Harrison, Suma, and Barnes (2009)	Not available	Teach Emotion Recognition and programming logic to children using Virtual Humans	GUI-based application	Not available
Battocchi et al. (2009)	Study 1, 70 boys with TD (mean age = 9.7 years) Study 2, 16 boys with ASD (mean age = 13.5 years)	Foster collaboration among ASD and TD	Multi-user tabletop device	Positive
Schmidt, Laffey, Schmidt, Wang, and Stichter (2012)	4 youth (11-14 years)	Social interaction	Virtual reality	Positive
Cheng, Chiang, Ye, and Cheng (2010)	3 boys (8-10 years)	Empathy	Virtual reality	Positive
Cheng and Ye (2010)	3 children (2 boys, 1 girl) 7-8 years old	Social competence (social interaction)	Virtual reality	Positive
Simões, Carvalho, and Castelo-Branco (2012)	4 (mean age 22)	Social interaction	Virtual reality, brain-computer interface	Positive
Parsons, Mitchell, and	12 (10 male, 2 female) 13–18	Social interaction	Virtual reality	Positive

Leonard (2004)	years			
Ben-Sasson et al. (2013)	Six dyads of children with HFASD (aged 8-11 years)	Social interaction	Multi-user tabletop device	Positive
Ho, Davis, and Dautenhahn (2009)	6 children (4-9 years)	Storytelling	Virtual reality	Positive
Sitdhisanguan, Chotikakamthorn, Dechaboon, and Out (2012)	12 children LFASD (3-5 years)	Shape matching skill and colour recognition skill	Tangible user interface	Positive
Therapy-related serious games:				
Anwar, Rahman, Ferdous, Anik, and Ahmed (2011)	1 child 10 years	Increasing Fluency in the Speech of the Autistic Children	GUI-based application	Positive
Beaumont and Sofronoff (2008)	49 children with AS	Emotional under-standing & social skills	GUI-based application	Positive
Cai et al. (2013)	15 participants: 6 – 17 years	Non-verbal communication	3-D serious game in 320° immersive room, Microsoft Kinect	Mixed
De Silva, Higashi, Lambacher, and Osano (2007)	20 children	Social interaction & communicational skills	GUI-based application	Positive
Giusti, Zancanaro, Gal, and Weiss (2011)	Not available	Joint performance, Sharing & Mutual planning	Multi-user tabletop device	Not available
Tanaka et al. (2010)	79 children, adolescents, and young adults with ASD	Facial abilities	GUI-based application	Positive
Wiederhold and Riva (2009)	Not available	Recognition of facial expressions	Xbox 360	Not available
Zhu, Sun, Zeng, and Sun (2011)	Not available	Social interaction	Virtual reality	Not available

A summary of participants, behaviours targeted in the study, technology used for the intervention of behaviours and results is provided below.

Behaviours: A number of behaviours have been supported in the serious games; however, facial expressions and emotions have been targeted and emphasized more by the researchers than others. Furthermore, it can be seen that none of the serious games have targeted behaviours associated with the vocabulary instruction of these children. This highlights a need for a game through which these children can learn, practice and improve behaviours related to vocabulary instruction.

Technology used: Different technologies have been used across the studies; however, virtual reality-based applications have been highly used, more than others. Microsoft Kinect, Xbox 360, tabletop interfaces and tangible user interface have also been used in different serious games.

Results: Most of the studies have reported that the evaluation of using serious games to support different behaviours among the children was positive. The authors of seven studies have not discussed about the results in the research articles. A study by Cai et al. (2013) have reported that the performance of the participants was mixed i.e., some of them were able to improve; however, others did not show any improvement. It was due to the fact that they were facing difficulty with interacting with the immersive environment. It can be concluded that serious games are highly useful to support different behaviours of children with ASD.

2.6.1 Discussion

Serious games have proven to be the most effective way to provide intervention of various skills to children with autism; however, they have been under-utilized to provide intervention of vocabulary to these children.

2.7 Executive summary of earlier sections

In section 2.1, behaviours associated with social communication skills of these children have been classified into four categories namely language comprehension, verbal communication, non-verbal communication and general behaviours. Nine behaviours in language comprehension can be used to support these children in the learning of different types of vocabulary.

An SLR on strategies and the use of CBIs to provide learning for these children is summarised in section 2.2.1. It was found that two strategies namely multimedia instruction and explicit instruction are more commonly used than the other three strategies i.e. indirect instruction, capacity methods and association methods. It was also found that CBI improved learning among these children.

In section 2.3, a review of all the instruction methods that could be used to teach vocabulary to these children is discussed. It was found that two instruction methods namely discrete trial training (DTT) and verbal response training (VRT) are more useful to teach and assess language among these children.

An SLR on modalities used in CBIs and the effectiveness of those CBIs in the learning, generalisation and retention of information among these children is presented in section 2.5. It was found that CBIs supported these children in the learning, generalisation and retention of information.

In section 2.6, a review on serious games related to these children is presented; it was found that serious games have been useful in providing learning of skills to these children but they have been under-utilised for the learning of vocabulary of children with ASD. During the search of serious games for the review, it was revealed that

researchers typically use serious game design frameworks to support them throughout the design process of serious games. The framework provides the structure, components and relationship between them as a guide. The purpose of each component in the framework may vary from one component to another; for instance, one component may represent the learning outcomes of the game, while another may represent the rules of the game and how the game changes over a period of time based on the performance of the child and user profile among others. Sections 2.1, 2.3 and 2.5 have reviewed autism behaviours, strategies, instruction methods and modalities related to ASD based on the two SLRs and two NRLs presented earlier in this chapter. These are regarded as the components related to ASD and in the game design they contribute specifically to the learning of vocabulary among children with autism. Table 2.6 briefly describes these components and their importance or usefulness in the design of serious game for these children.

Table 2.6: Components from ASD and their importance in the design of serious games for children with autism

Component	**Importance/usefulness**
Autism behaviours	The children with ASD have a set of behaviours related to vocabulary instruction as well as general behaviours related to other skills. The support of general and specific behaviours of vocabulary instruction can facilitate these children to develop behaviours in which they face difficulties.
Strategies	The use of multiple strategies for the vocabulary instruction in serious games can motivate children with ASD and allows them to stay focused on the learning.
Instruction methods	Each instruction method has its own pros and cons. The use of appropriate instruction method related to vocabulary instruction in the serious game can provide effective learning environment to these children so that they can improve their behaviours.
Modalities	The use of multiple modalities for the input can give freedom to these children in the way they would like to communicate with the serious game. The use of multiple output modalities together can provide better learning experience to the child.

From the review of serious games in section 2.6, it was found that a number of serious games have been developed for these children; however, they have not been exploited to support these children in the learning of vocabulary. Therefore, to enrich the components to design serious games for vocabulary learning of these children, the next chapter provides an insight and understanding on how existing serious game design frameworks for children with ASD are constructed and identify the components used in those frameworks. This would reveal other components that can be incorporated into the design of serious games for these children in addition to the components presented in Table 2.6.

CHAPTER 3: COMPONENTS TO DESIGN SERIOUS GAMES FOR CHILDREN WITH AUTISM

This chapter reviews, analyses and identifies components to design serious games for children with autism. They involved three main parts which are the review of existing serious games design frameworks, the review of game attributes of serious games, and the review of theories of learning and psychology.

3.1 Review of existing serious games design frameworks

Section 3.2 reviews the frameworks for children with ASD and the method used to conduct the review is described as follows:

A systematic search was carried out to locate research articles in six databases: 1) IEEE, 2) ACM, 3) ScienceDirect, 4) Springer, 5) Sage, and 6) Google Scholar. A framework was included for further investigation if it fulfilled the following criteria:

1) Framework discusses theoretical and pedagogical aspects used to develop framework
2) Framework discusses the game components to be considered for the design of serious games
3) Framework focuses on computer-based games
4) Framework caters to single-player games only
5) Framework is descriptive rather than abstract to understand it

A set of keywords were used to carry out this search process; the search was restricted between January 2000 and December 2015. An example of Boolean search strings and keywords used to search all three types of frameworks in the mentioned databases are given below:

Boolean search strings to locate frameworks for children with ASD:

("Serious game" OR "game" OR "game-based") AND ("framework" OR "model") AND ("autism" OR "autism spectrum disorder" OR "ASD")

3.2 Serious games design frameworks for children with ASD

The objectives of this review are to identify:

- The presence of components related to ASD from Table 2.6 (section 2.7 of chapter 2) in the framework
- Other components incorporated into the framework
- Underlying structure which has been used as a basis in the framework.
- The type of framework (i.e., generic or specific): the former type of framework can be used to support various behaviours whereas the latter can only be used to support particular behaviours.

3.2.1 Result

The literature search revealed one framework (Park et al., 2012) which was shortlisted for further analysis as it fulfilled above-mentioned criteria. The authors have developed a framework as shown in Figure 3.1 by integrating Kolb's experiential learning model and Piaget's cognitive development model together to specifically teach emotions to children with ASD. The authors have described six components (see Table 3.1) from two theoretical models that one must take into consideration in the design of serious games for these children to learn emotions. These models consider all the stages of the cognitive and developmental processes and the learning style followed by an individual. Recognizing and matching are related to learning. The recognizing process also facilitates in the recognition of expressions. Observing is a process of watching.

Understanding is similar to observing in terms of using abstract/mental activities in the learning process. Generalizing is an ability to apply an emotion in different contexts. Mimicking relates to testing in a particular context.

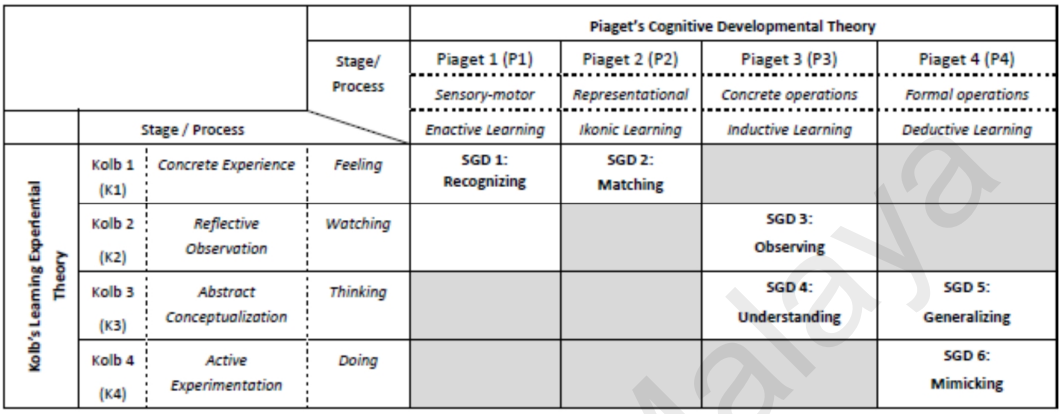

Figure 3.1: Theory-driven serious game design (SGD) framework by Park et al. (2012)

Table 3.1 shows the summary of one framework in the form of: 1) citation of the research, 2) ASD components, 3) other components from the framework, 4) underlying structure referred to as structure, and lastly 4) the type of frameworks referred to as type. It can be seen that emotions targeted in the framework are regarded as autism behaviours. The six components (i.e., recognizing, matching, observing, understanding, generalizing and mimicking) constitute an instruction method to teach emotions to these children. The remaining two ASD components (strategies and modalities) are not part of the framework. Park et al. (2012) have created their own structure rather than using any existing underlying structure to design games for these children to learn emotions.

Table 3.1: Summary of frameworks for children with ASD

Citations	ASD components				Other components from framework	Underlying structure	Type
	Autism behaviours	Strategies	Instruction methods	Modalities			

Park et al. (2012)	Emotions	ND	1. Recognizing 2. Matching 3. Observing 4. Understanding 5. Generalizing 6. Mimicking	ND	ND	Own structure	Specific

Note. ND = Not discussed.

3.2.1.1 Visual approximation of components in serious games for children with ASD

Watkins (2015) has identified five popular games that help children with ASD to improve different skills; these games and the skills targeted are shown in Table 3.2. The uniform resource locators (URLs) mentioned in the footnote are links associated with each game which provide descriptions of the game as well as another link to download or buy it in order to play the game.

Table 3.2: Five popular games among children with ASD

Game	Skills targeted	Platforms/console
Minecraft[2]	Social interaction	Android, iPad, iPhone, Mac, Ninten do Wii U, Online, PC, PlayStation 3, PlayStation 4, PS Vita, Xbox 360,Xbox One
If…[3]	Social and emotional learning (SEL) skills	iPad
New Super Mario Bros. U[4]	Motor skills	Nintendo Wii U
Portal 2[5]	Social communication skills, self-awareness, and self-control	Mac, PC, PlayStation 3,Xbox 360
Draw Something 2[6]	Motor skills	Android, iPad, iPhone, iPod

[2] http://learningworksforkids.com/playbooks/minecraft/
[3] http://learningworksforkids.com/playbooks/if/
[4] http://learningworksforkids.com/playbooks/new-super-mario-bros-u/
[5] http://learningworksforkids.com/playbooks/portal-2/
[6] http://learningworksforkids.com/playbooks/draw-something-2/

A quick visual approximation was carried out by going through the screens of each game mentioned in the table above; the purpose of approximation is to identify a corresponding representation of components from table 3.1 in each screen, and any other components that have been used in order to arrive at a rough estimation on the use of components among these games. It was found that most of the components from Table 3.1 are used in each game; it was also found that each game has used a number of other components as well. For instance, *identity* that was given to a child typically through an avatar when they are playing the game, *content* which increases in complexity as they progress and *scaffolding* to support children throughout the game; these are a few components that have been used in the games mentioned. These components are commonly used components in the serious game design for children with ASD or typical children. The current review of framework for children with ASD in this section has highlighted only one framework. Therefore, the review of components was extended to serious games design frameworks for typical children to identify these commonly used components to design serious games.

These components can facilitate in the design of serious games for children with autism but their use may vary from designs for typical children.

3.3 Serious games design frameworks for typical children

The objectives of this review are to identify:

- Components incorporated into the framework and are related to typical children
- Underlying structure of the framework
- The type of framework (i.e., generic or specific)

The method described in section 3.1 was also used to conduct review in this section. Boolean search strings used to locate frameworks for typical children:

("Serious game" OR "game" OR "game-based") AND ("framework" OR "model") AND ("child" OR "kid" OR "teen" OR "youth" OR "young")

3.3.1 Result

The literature search revealed two frameworks which were shortlisted for further investigations (Annetta, 2010; Obikwelu & Read, 2012). A brief summary of these two frameworks is given below:

3.3.1.1 A framework by Annetta (2010)

Annetta (2010) has proposed a framework (see Figure 3.2) for the design of educational game. These game components are nested among each other and grounded in research and theory of education and psychology, instructional technology and the learning sciences. The existing studies which have focused on the design and development of educational games for class from grade 5 through graduate school have been used as a basis to derive components for this framework. According to the author, the user is given an identity in the game. The motivating factors are used to get the user to be immersed in the game for learning process. Interacting with other players, virtual agents or the game itself also play a vital role in the immersion of the user in the game. The game becomes increasingly more complex as the player progresses through the game. The assessment and feedback are given to the user through the process of informed teaching, while the instruction explains how the learning takes place in the game.

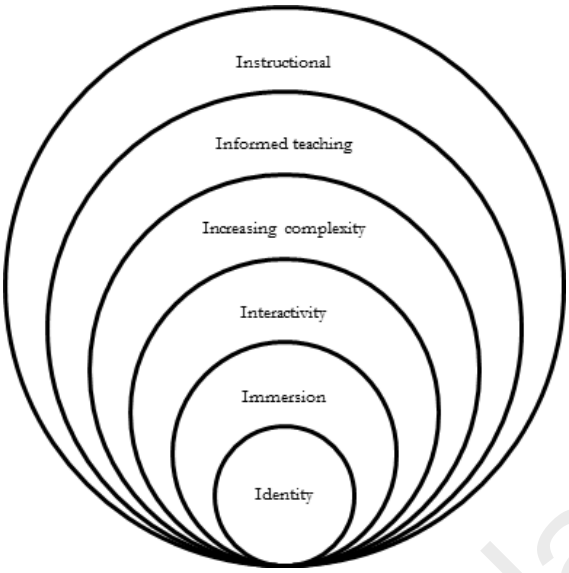

Figure 3.2: Redrawn nested elements of educational game design by Annetta (2010)

3.3.1.2 A framework by Obikwelu and Read (2012)

Obikwelu and Read (2012) have created a framework to determine the extent to which researchers have adapted the pedagogical aspects of constructivism theory in the serious game to facilitate learning process of a child. The constructivist framework and its components are shown in Figure 3.3. Modelling is a form of demonstration followed by imitation which is frequently used as a way of helping the user to make progress in games. Reflection enables a player to compare the processes they use to solve problems to those of others. Scaffolded Exploration guides users to solve problems on their own. Users make and follow their own strategies known as strategy formation to solve problems in the game. Debriefing helps users to explore what went on, talk about their experiences, develop insights, reduce negative aspects of the activity and connect the activities to their real-life situations. The players use technique of articulation to share experiences and knowledge acquired.

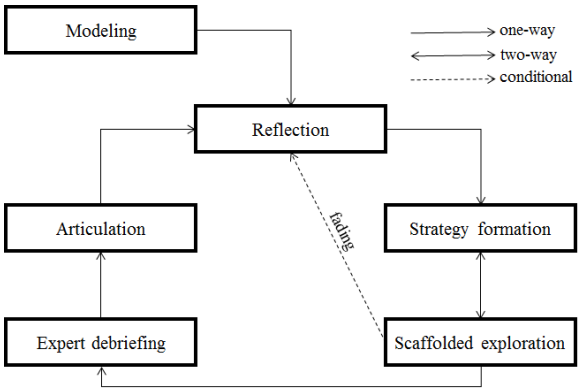

Figure 3.3: Serious game constructivist framework for children by Obikwelu and Read (2012)

Table 3.3 provides a summary of both frameworks; Annetta (2010) has considered 6 components in their framework while Obikwelu and Read (2012) have used 7 components in their framework which are discussed above. The framework by Annetta and the one by Obikewelu & colleagues have created their own structure rather than using any underlying structure. These frameworks are generic and can be used to design games that can target different skills related to children.

Table 3.3: Summary of frameworks for typical children

Citations	Components	Underlying structure	Type
Annetta (2010)	1. Identity 2. Immersion 3. Interactivity 4. Increasing complexity 5. Informed teaching 6. Instructional	Own structure	Generic
Obikwelu and Read (2012)	1. Modelling 2. Reflection 3. Strategy formation 4. Scaffolded exploration 5. Expert debriefing 6. Articulation 7. Fading	Own structure	Generic

3.3.1.3 Visual approximation of components in serious games for children with ASD

Another quick visual approximation was performed on the serious games presented in the Table 3.2 of section 3.2.1.1. The purpose of this approximation was to identify a corresponding representation of components from Table 3.3 that have been used in the

games and also to determine other components which are not presented in the table. It was found that most of the components from the table are used in the serious games. A few additional components were also found in these games which are not present in the table. These components include the *game genre* which is known as the type of the game, *learning activity* that the child needs to undergo as a part of learning *content* and the *achievements* gathered in the activities are some of the examples. These components are the commonly used components in serious games across different types of users including children with ASD, typical children or typical users. The review of components was further extended to serious games design frameworks for typical users in order to identify all possible components that could be used in the design of serious games for children with autism.

3.4 Serious games design frameworks for typical users

The objectives of this review are to identify:

- Components incorporated into the framework
- Underlying Structure of the framework
- The type of framework (i.e., generic or specific)

The method described in section 3.1 was also used to conduct review in this section. Boolean search strings used to locate frameworks for typical users:

("Serious game" OR "game" OR "game-based") AND ("framework" OR "model")

3.4.1 Result

The search for the frameworks of serious games for typical users revealed 6 frameworks. These frameworks can be used for one or more tasks related to design, development or evaluation of games. However, three frameworks (Garris, Ahlers, &

Driskell, 2002; Winn, 2008; Yusoff, Crowder, Gilbert, & Wills, 2009) met the selection criteria and were shortlisted for further investigations. Following is a brief summary of these frameworks.

3.4.1.1 A framework by Garris et al. (2002)

A basic input-process-output model of instructional games and learning is defined by Garris et al. (2002) which is used as a basis in most of the game-based studies in recent past. The game model and its components are shown in Figure 3.4. The instructional content refers to the intended material for the user to learn through the game. Game characteristics indicate features of the game that support learning and engagement. The characteristics include fantasy, rules/goals, sensory stimuli, challenge, mystery and control. The user makes various subjective judgments as they start playing the game to determine if the game is fun, interesting and engaging. The affective judgments that are formed from initial and on-going game play determine the direction, intensity, and quality of further user behaviour. The goals to be achieved from playing serious games are known as learning outcomes. Debriefing is the process of performing a review of all the events that took place in the game. According to the authors of this model, the user is presented with a blended material which is composed of instructional contents and game characteristics. Thereby, a continuous process cycle will have 1) user judgment (enjoyment and interest), 2) user behaviour, and lastly 3) system feedback, follow one another. It is assumed by the authors that a successful pairing of instructional contents and game characteristics can result in repetitive and self-motivating gameplay.

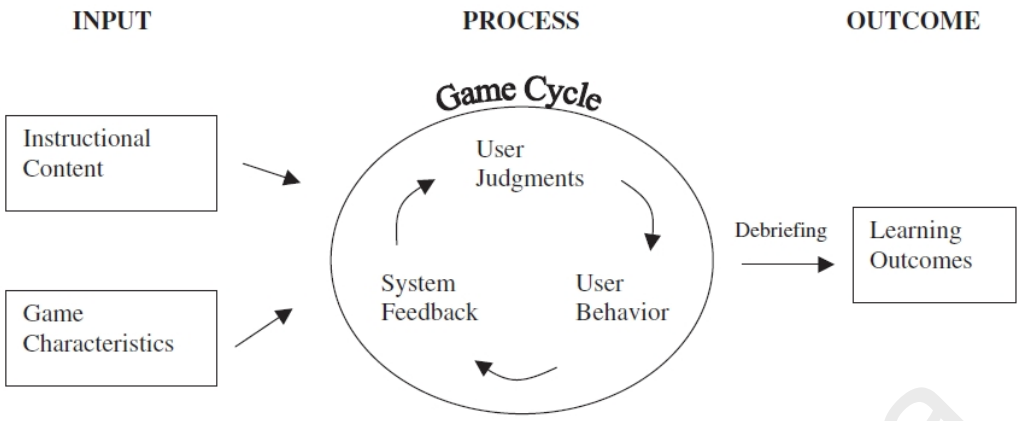

Figure 3.4: Input-Process-Outcome Game Model by Garris et al. (2002)

3.4.1.2 A framework by Winn (2008)

Winn (2008) has mentioned about the lack of common language and standardized practices available to design a serious game. The author has developed a design, play and experience (DPE) framework to design serious games. It is an expansion of mechanics, dynamics and aesthetics (MDA) framework that is used to design entertainment games. The three game components include design, experience and play. The game designer designs the serious game, while the player plays it and improves his or her experience of playing games. This framework is divided into four layers where each layer covers all three game components (design, experience and play). The layers are: learning, storytelling, gameplay and user experience. The DPE framework and its components are shown in Figure 3.5. The components are discussed according to the layer in which they are placed.

Learning layer: The designer designs the contents and pedagogy used in teaching the user when they are playing the game; this leads them to gain experience and attain the learning outcomes.

Gameplay layer: The designer defines the rules and regulations of the game, what the user can do, challenges that the user will face, and etc. Dynamics are the changes that

occur in the game when rules are instantiated as user interaction starts. The resulting experiences and emotions gained by the user are referred to by the component affect.

Storytelling layer: Each game has two types of stories: the designer's story and the user's. The storytelling is the designer's story in the game. The tools that the designer uses to create storytelling include setting, character design and narratives. The storytelling that occurs during the game includes: 1) designer's story, 2) interaction, and 3) the choice that the user make throughout the game. The resulting experience creates player's story.

User experience layer: the goal of the designer is to develop a game which is transparent enough that the user will be immersed in the game environment. This in consequence will increase learning experience as the user can focus on other layers (gameplay, storytelling and learning) rather than thinking of how to interact with the game.

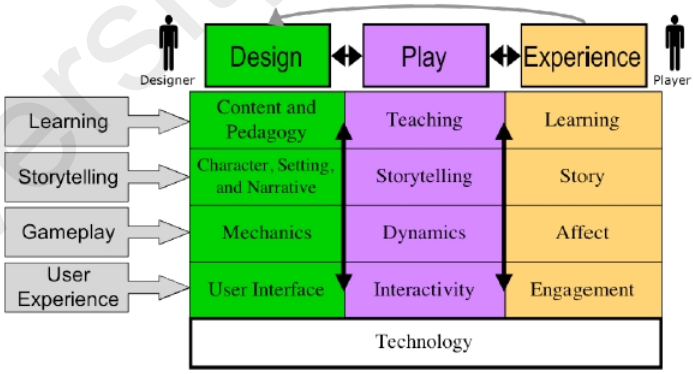

Figure 3.5: Expanded DPE Framework by Winn (2008)

3.4.1.3 A framework by Yusoff (2010)

Yusoff (2010) has developed a conceptual framework by combining a learning and pedagogy theory with game requirements for the designers and practitioners to design serious games for effective learning of the user. This framework can also be used to

measure the achievement of the learning outcomes of serious game. The author has also identified serious game attributes that would support effective learning by using serious games. This conceptual framework is an evolution of the learning model by Garris et al. (2002) and uses technology acceptance model (TAM) for validation. The serious game framework and its components are shown in Figure 3.6. Instructional content, game attributes, and learning outcomes are the same as of described earlier. Capability refers to the type of skills (cognitive, psychomotor, or affective skills) that the learner is to develop while playing the game. The users are engaged in the game to learn through learning activities. Reflection is where the learner thinks about the purpose of the learning activities that have been undertaken, and decides the strategy to apply during the next activity. Game genre refers to the type of game being played. Game mechanics are the rules and regulations in the game. The achievements done by the learner are known as learner achievements. The author has discussed 11 game attributes which include: incremental learning, linearity, attention span, scaffolding, transfer of learned skills, interaction, learner control, practice and drill, intermittent feedback, rewards, situated and authentic learning and accommodating to the learner's styles.

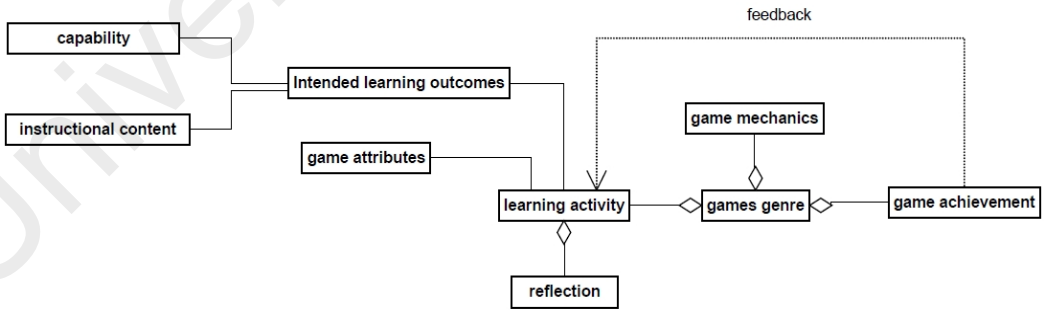

Figure 3.6: Conceptual Framework for Serious Games shown as a Structural Class diagram by (Yusoff, 2010)

Table 3.4 shows a summary of the three frameworks - (Garris et al., 2002), (Winn, 2008) and (Yusoff, 2010). The frameworks have been developed based on 7, 15 and 9 components respectively. Garris and colleague have created their own structure while

Winn has used MDA by Hunicke, LeBlanc, and Zubek (2004), and Yusoff has used IPO by Garris and colleague as an underlying structure. The structure of each framework is generic and can be used to design games that can target different contents and skills irrespective of the users.

Table 3.4: Summary of frameworks for typical users

Citation	Components			Underlying structure	Type
Garris et al. (2002)	1. Instructional content 2. Game characteristics 3. User judgment	4. System feedback 5. User behaviour	6. Debriefing 7. Learning outcomes	Own structure	Generic
Winn (2008)	1. Content 2. Pedagogy 3. Character 4. Settings 5. Narrative	6. Mechanics 7. User interface 8. Teaching 9. Storytelling 10. Dynamics	11. Interactivity 12. Learning 13. Story 14. Affect 15. Engagement	MDA by Hunicke et al. (2004)	Generic
Yusoff (2010)	1. Instructional content 2. Intended learning outcomes 3. Game attributes	4. Game genre 5. Game mechanics 6. Learning activity	7. Reflection 8. Capability 9. Game achievement	IPO by (Garris et al., 2002)	Generic

Comparing the components of frameworks for typical children from Table 3.3 and those of frameworks for typical users from Table 3.4, it can be seen that a number of components like identity, instructional, interactivity, reflection, and expert debriefing among others are commonly used in both types of framework. This shows that such components are widely used in serious games irrespective of the type of user. Furthermore, there are other components like learning outcomes, learning activity, game attributes, game mechanics, and game dynamics among others which are specifically used in the frameworks for typical users. Although these components are not emphasised in the frameworks for children with ASD or typical children; however, they play a role in the serious games and can contribute in the designs of serious games for children with autism. For instance, learning outcomes can be used to specify all the outcomes that a player is expected to achieve by the end of the game. Game mechanics can be used to create rules and regulations of the game, learning activities can be used

to create a set of activities in which the player is given exposure of the contents learned throughout the game, and performs set of tasks to improve their understanding. Learning activities are the set of activities designed to keep players actively involved when they are playing the game. The effective design of these activities ensures that players stay engaged and immersed without getting bored.

3.4.2 Discussion

The key findings from the review of the six frameworks are presented in the following sub-sections.

3.4.2.1 Components of the framework:

From the components of frameworks for children with ASD (Table 3.1 in section 3.2), a total of two components namely autism behaviours and instruction methods have been used in the framework by (Park et al., 2012). The six components of framework namely recognising, matching, observing, understanding, generalising, and mimicking were categorised as instruction methods. Both of the mentioned components contribute in the design of serious games from the perspective of children with ASD.

From the components of frameworks for typical children (Table 3.3 in section 3.3), a total of 13 components were found which include 7 components from both (Annetta, 2010) and (Obikwelu & Read, 2012). These components contribute in the design of serious games from the children's perspective.

From the components of frameworks for typical users (Table 3.4 in section 3.4), 31 components were found altogether which include 6 from (Winn, 2008), 9 from (Garris et al., 2002) and 15 from (Yusoff, 2010). These components contribute in the design of serious games in general (i.e., irrespective of the type of users).

A total of 50 components were found from the six frameworks reviewed in sections 3.2 – 3.4. These components are further analysed and synthesised in section 3.5 to group similar components together and remove any redundant components in intra- and inter-frameworks.

3.4.2.2 Underlying structure used in the framework

From the six frameworks, the framework by Yusoff (2010) has used input, process, output (IPO) model by Garris et al. (2002), and the framework by Winn (2008) has used mechanics, dynamics, and aesthetics (MDA) framework by Hunicke et al. (2004) as bases to construct their framework on, while the remaining frameworks have constructed their own structures.

3.4.2.3 The type of framework (generic or specific)

From the six frameworks, it was found that the framework by Park et al. (2012) is a specialised framework to design serious games for children with ASD to learn emotions. The remaining frameworks are generic as they can be used to design different types of serious games based on the needs of the user.

3.5 Grouping of components from frameworks

The 50 components found from the review of six serious games design frameworks in earlier sections were placed outside the rectangle as shown in Figure 3.7 for further analysis and synthesis. Each framework is distinguished from one another as follows:

1) The components in each framework are written with different colours. The colours used are: purple for (Park et al., 2012), blue for (Annetta, 2010), orange for (Obikwelu & Read, 2012), green for (Garris et al., 2002), red for (Yusoff, 2010) and black for (Winn, 2008).

2) A coloured number enclosed in a matching-coloured circle that refers to the citation of the framework is placed near these components. The numbers used are: 1 for (Park et al., 2012), 2 for (Annetta, 2010), 3 for (Obikwelu & Read, 2012), 4 for (Garris et al., 2002), 5 for (Yusoff, 2010) and 6 for (Winn, 2008).

3) The components in each framework are separated by a line.

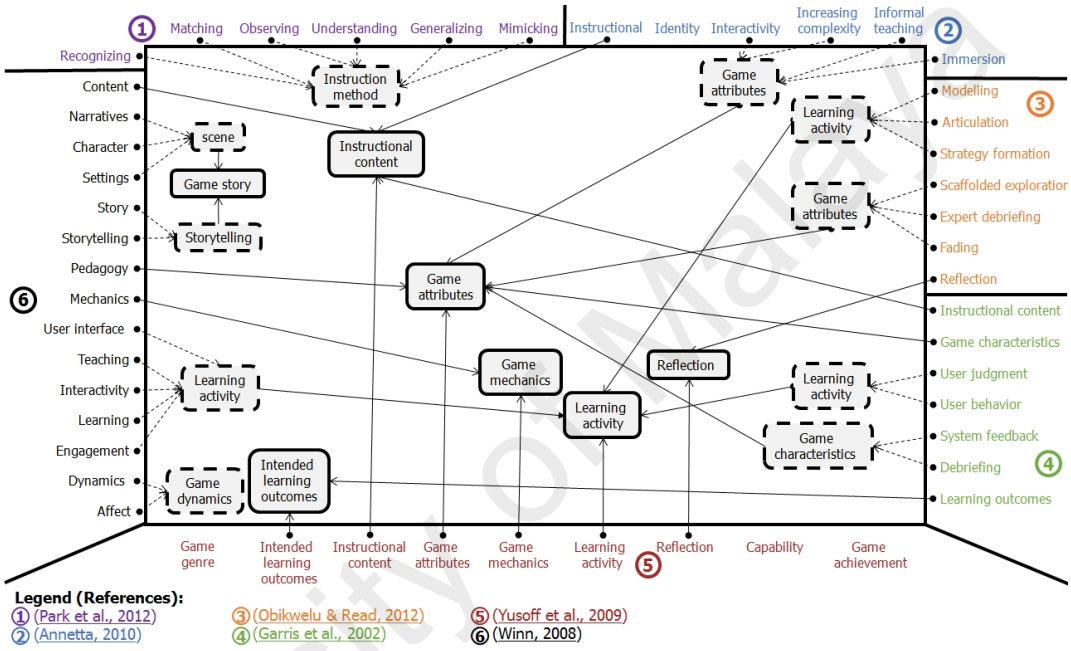

Figure 3.7: Compilation of components from all three types of frameworks

A two-step process as described below is carried out to group a list of components based on the results from the review of all three types of frameworks.

3.5.1 Grouping within the intra-frameworks:

While reading through the descriptions of components across the frameworks, it was found that some of the components within the framework are logically related to each other. Therefore, the first step was to identify those components and combine them together using a process similar to that of an affinity diagram. These logically related components are linked to a new component with a name which is based on the essence of details in the descriptions of all the components. This name perhaps can be similar to

a component that already exists within the same framework, or any other component in a different framework, as long as the details in its description match with the details in the descriptions of all the components to be linked. The name of the new component is shown in a dashed rounded rectangle, placed within the rectangle, and all the logically related components point towards this new component with dashed arrows. For instance, system feedback and debriefing in (Garris et al., 2002) are related to another component called game characteristics which already exists within the framework. Therefore, a new component was named as game characteristic and both components (system feedback, and debriefing) were linked to the new component. Table 3.5 shows all the related components within the frameworks which were merged together to create a new component. The name of the new components was specified based on the names used by the similar components in other frameworks.

Table 3.5: Grouping of components within the intra-frameworks

Related components within the framework	**Citation**	**New component created**
Recognizing, matching, observing, understanding, generalizing and mimicking	(Park et al., 2012)	Instruction method
Interactivity, increased complexity, informal teaching and immersion	(Annetta, 2010)	Game attributes
Modelling, articulation and strategy formation	(Obikwelu & Read, 2012)	Learning activity
Scaffolded exploration, expert debriefing, fading and reflection	(Obikwelu & Read, 2012)	Game attributes
User judgment and user behaviour	(Garris et al., 2002)	Learning activity
System feedback and debriefing	(Garris et al., 2002)	Game characteristics
Dynamics, affect	(Winn, 2008)	Game dynamics
User interface, interactivity, learning and engagement	(Winn, 2008)	Learning activity
Story, storytelling	(Winn, 2008)	Storytelling
Narratives, characters, settings	(Winn, 2008)	Scene

3.5.2 Grouping within the inter-frameworks:

It was also found that there are components across the frameworks which are similar to each other based on the details in their descriptions. In some cases, all these components had similar names; for instance, instructional contents in (Garris et al., 2002) & (Yusoff, 2010), contents in (Winn, 2008) and instructional in (Annetta, 2010). There were few cases where descriptions matched but the names were not similar; for instance, Garris and colleague named a component as 'game characteristics' while Yusoff named it as 'game attributes' to refer to the same information. All such components were identified and linked to a new component with a more commonly used name; the name of the new components is shown in a rounded rectangle, placed inside the rectangle and all the linked components point towards this component. Table 3.6 shows all the related components across the frameworks which were merged together to create the new components. The name of the new components was specified in a way that it can either resemble the names or the gist of corresponding related components.

Table 3.6: Grouping of components within the inter-frameworks

Related components and citation	**New component created**
1. Reflection: (Obikwelu & Read, 2012) and (Yusoff, 2010)	Reflection
1. Learning activity: (Obikwelu & Read, 2012) (Garris et al., 2002) (Yusoff, 2010) (Winn, 2008)	Learning activity
1. Game mechanics: (Yusoff, 2010) 2. Mechanics: (Winn, 2008)	Game mechanics
1. Pedagogy: (Winn, 2008) 2. Game attributes: (Yusoff, 2010) (Annetta, 2010) and (Obikwelu & Read, 2012) 3. Game characteristics: (Garris et al., 2002)	Game attributes
1. Instructional: (Annetta, 2010) 2. Instructional content: (Garris et al., 2002) and (Yusoff, 2010) 3. Content: (Winn, 2008)	Instructional content
1. Learning outcomes: (Garris et al., 2002) 2. Intended learning outcomes: (Yusoff, 2010)	Intended learning outcomes
1. Scene and storytelling: (Winn, 2008)	Game story

There were four components (identity, game achievement, capability, and game genre) which did not have any other matching components; these components are the ones which do not have any outgoing arrow towards another component. Each of these components is regarded as an independent component.

Table 3.7 shows a total of 20 components from the total of 50 components after grouping similar components and eliminating redundant components in intra-frameworks (see Table 3.5) and inter-frameworks (see Table 3.6).

Table 3.7: Three types of frameworks and their components

S#	Classification of components	Game components:	Frameworks for children with ASD	Frameworks for typical children		Frameworks for typical users		
			Park et al. (2012)	Annetta (2010)	Obikwelu and Read (2012)	Garris et al. (2002)	Winn (2008)	Yusoff (2010)
1	Components from ASD	Autism behaviour	✔					
2		Instruction method	✔					
3		Strategies						
4		Modalities						
5	General game components	Capability						✔
6		Instructional contents				✔	✔	✔
7		Learning outcomes				✔		✔
8		Learning activity			✔	✔		✔
9		Game genre						✔
10		Game mechanics					✔	✔
11		Game dynamics					✔	
12		Scene			✔		✔	
13		Storytelling					✔	
14		Narratives		✔		✔	✔	
15		Characters		✔			✔	
16		Game attributes				✔		✔
17		Reflection			✔			✔
18		User profile		✔				
19		User achievements				✔		✔
20		Debriefing				✔		

Table 3.5 shows that nine components which have been grouped as game attributes; this is in addition to the six and 11 game attributes identified by (Garris et al., 2002) and

(Yusoff, 2010) respectively. The number of game attributes incorporated and how they are used in the design to support learning and engagement within the game environment vary from one game to another. This support would be limited if only a few attributes are known or little is known about the details of these attributes. There are other attributes that can also contribute to the learning and engagement of children with autism in serious games in addition to the above-mentioned game attributes. These include, for example, adding an element of surprise in the game to keep the player interested in the game, providing an opportunity to interact (be it with another player within, or physically outside the game environment), and continuously providing motivation to the player among others (Wilson et al., 2009). Consequently, a review of game attributes was conducted.

3.6 Review of game attributes

The backward and forward reference-searching techniques were used to search and compile a list of all the game attributes. The former technique involves identification of all the references or works cited in the chosen article to determine the origin of game attributes and progress that has been made over the period of time until the publication date of the chosen article. The latter technique involves identification of all the articles in which the chosen article is cited; the purpose of this technique is to determine how the game attributes from the chosen article have evolved in recent articles.

The backward reference searching revealed the first work on developing taxonomy of game attributes that was carried out by (Garris & Ahlers, 2001). These authors revealed 39 different game attributes which can be used in the games. A later study by Garris et al. (2002) suggested that only six game attributes are essential for learning based on IPO. Wilson et al. (2009) expanded this work by connecting game attributes

with the learning outcomes. The authors identified 18 potential game attributes that can be used in different games. These attributes can also be used as a guideline to determine the potential learning outcomes of the game. A research study conducted by Bedwell, Pavlas, Heyne, Lazzara, and Salas (2012) found that there are a lot of overlaps between different game attributes. Therefore, they recruited subject matter experts (SME) to collapse this list of 18 attributes and come up with the non-overlapping set of attributes using card-sort technique. The result of this exercise revealed 10 categories in which different attributes were merged.

Table 3.8 shows a summary of all the attributes found across the different studies. It can be seen that there is one attribute called control which is used in all the studies. This attribute refers to the fact that there is a need to give control to the user so that they can choose the material which can change the overall flow of the game. Another attribute which most of the studies focused on is feedback. Two attributes which include help and support, and debriefing are not explicitly emphasised in the studies presented in the table but these attributes are commonly used in various serious games. Both attributes were added as they can support in the learning of children with autism. The selection and use of the attributes presented in the following table may vary from one game to another. A brief definition of all attributes is provided in Appendix C.

Table 3.8: Summary of game attributes found in various studies

S#	Attributes	Studies				
		Garris et al. (2002)	Wilson et al. (2009)	Yusoff (2010)	Murphy (2011)	Bedwell et al. (2012)
1	Fantasy	✔	✔			✔
2	Mystery	✔	✔			✔
3	Rules/goals	✔	✔			✔
4	Sensory Stimuli	✔	✔			✔
5	Challenge	✔	✔			✔
6	Control	✔	✔	✔	✔	✔
7	Feedback		✔	✔	✔	✔

8	Language/communication		✔			✔
9	Assessment		✔		✔	✔
10	Progress		✔			✔
11	Adaptation		✔			✔
12	Conflict		✔			✔
13	Surprise		✔			✔
14	Location		✔			✔
15	Interaction (equipment)		✔	✔		✔
16	Interaction (interpersonal)		✔			✔
17	Interaction (social)		✔			✔
18	Pieces or Players		✔			✔
19	Representation		✔			✔
20	Safety		✔			✔
21	Practice and drill			✔	✔	
22	Incremental learning			✔		
23	Linearity			✔		
24	Attention span			✔		
25	Scaffolding			✔		
26	Transfer of learned skills			✔		
27	Rewards			✔		
28	Situated and authentic learning			✔		
29	Accommodating to learner's style			✔		
30	Motivation				✔	
31	Positive feelings				✔	
32	Intensity				✔	

During the review of game attributes, it was also found that these attributes are based on a theory of psychology and theories of learning. The use of one or more of these game attributes in the game design means that the design covers relevant theories; this sets the ground to review mentioned theories in the next section.

3.7 Related theories

This section describes the theories of learning and theory of psychology, and provides the mapping of each game attributes to the relevant theory.

3.7.1 Theories of learning

According to Klein (1996), learning is a process; therefore, it is necessary that learning brings changes in the behaviour if it does bring changes in the behaviour of a

person then it remains permanent. When a user learns new behaviours, they usually forget the previously learned behaviours. Therefore, it is important to understand the learning and cognitive theories whenever there is a need to design a system to provide learning for the user. In this part of the chapter, three theories i.e., Behaviourism, Cognitivism, and Constructivism are discussed and will be referred to as learning theories throughout the study which also discusses the theory of psychology.

2.1.1.1.Behaviourism

The theory of behaviourism is about the study of behaviours that can be observed and measured (Good & Brophy, 1990). According to this theory, the mind of a human being is considered as a "black box" in the sense that response to stimulus can be observed quantitatively, while completely ignoring thinking processes occurring in the mind. The behaviourist name Edward Thorndike has developed an original framework of stimulus response and its theory is comprised of three laws (Belkin & Gray, 1977):

1. Law of effect is related to the emotional characteristics of a person, which has a direct relationship with motivation. It states that connection between stimulus and response can be strengthened when it is positively acknowledged and rewarded, but the connection can also be weakened if it is negatively acknowledged and rewarded. Thorndike later revised this law when the author found that in certain cases negative acknowledgement and reward (punishment) did not weaken bonds among stimulus and response, and similarly in a few cases, pleasing complements did not increase performance.
2. Law of exercise states that behaviours and tasks most often repeated are remembered for longer period of time than others. It provided basis for practice and drill exercise. Students learn more and more and are also able to retain information for a longer duration when they are provided environment to practice and repeat it a

couple of times to gain information. Thorndike found that performance is increased if proper feedback is given towards the end of practice.

3. Law of readiness is about the concentration and eagerness of the user while being involved in the process of learning. They learn and gain more knowledge when they are physically, mentally, and emotionally ready to learn. However, they may not learn anything if they do not perceive or understand any reason behind learning. It states that motivated users tend to learn more than unmotivated users.

Murphy (2011) has also described different laws of learning including laws by Thorndike and two additional laws which are related to the theory of behaviourism:

1. Law of intensity states that learning material can most likely be retained by the child for longer time duration if it is intensely taught. An example of this law is a situation in which the child learns a lot from an exciting teacher than just reading materials from the textbook. Intensity heightens out perceptions and allows the child to put full concentration on the learning material which ultimately increases the overall learning.
2. Law of recency states that learning is degraded over a period of time. It is easy to remember things that were learned recently. This is why, teachers usually repeat, reemphasize and restate important points towards the end of class so that they are remembered the most and can be easily recalled in the next lecture. The same reason applies in books; by repeating key points at the end of chapters they can be recalled effortlessly in the start of the next chapter.

2.1.1.2.Cognitivism

Cognitive theory explains behaviours of humans by understanding how learning is processed inside the brain. According to Piaget's stages of cognitive development

theory Piaget (1955), human intelligence is developed in various stages throughout their life by learning gradually to acquire knowledge, construct a new knowledge by combining knowledge acquired and lastly making use of new knowledge. Piaget explained how and why mental development occurs using four basic concepts namely schema, assimilation, accommodation and equilibrium (Wadsworth, 1996). Piaget has described schema as a pattern of thoughts or behaviours; schemas are formed based on two processes including organization and adaptation of information. Organization is all about how information can be systematically stored in the memory so that it can be efficiently retrieved and used. The next process of adaptation indicates how learner adapts the acquired information into natural environment. For a child to adapt these changes into a new environment, they make use of assimilation and accommodation. The existing schema changes over a span of time as learner gains more experience, acquire new information or modify existing information. Assimilation happens when a learner tries to incorporate new and similar information into existing knowledge. When this situation occurs, learner typically takes some time to adjust before new information is assimilated in the memory (Atherton, 2009; McLeod, 2007). An example of this is; a child is taught about a horse, they learn that a horse has furs, four legs and a tail. Therefore, when the child sees a zebra, they start calling it a horse. Accommodation is another part of the adaptation process in which existing schema is either changed or altered in the light of new information or new experience. During this process, new schemas may also be developed. Taking the earlier example into account, when the child is corrected and told that the animal they see is a zebra, they call it a zebra. Equilibrium allows children to strive and balance between applying existing knowledge (assimilation) and changing behaviour to account for new knowledge (accommodation.) Taking the same example of horse and zebra; when a child calls a horse a zebra, they

enter into a state of disequilibrium; however, after correcting them about the name of the animal, the transition from taking the incorrect name to taking the correct name, the child enters into a state of equilibrium. Each child is motivated to restructure their knowledge when they find a conflict between their existing knowledge and their predictions (disequilibrium.)

One of the most significant cognitive theories in learning is the Information Processing (IP) theory. IP theory approaches learning through the concept of memory and how it is retrieved. There are several models in IP theory that explain how information is processed and accessed but basically it involves three primary stages; encoding, storage, and retrieval. Figure 3.8 shows an information processing model. Encoding happens when information is sensed, perceived, and attended to. The human being receives information through their sensory receptors; ears, eyes, nose, mouth or sense of touch. Sensory store keeps information stored for a while before it is processed. This unanalysed information is lost at the end of that time unless it is identified during initial processing stage (Reed, 2009). A separate store exists for each of the senses. Pattern recognition is applied to find familiar pattern in the information already stored in the memory. If the pattern does not match and the person finds that the new information is useful, they may want to store this information in their memory. The retrieval stage is when the information is accessed from the memory when it is required.

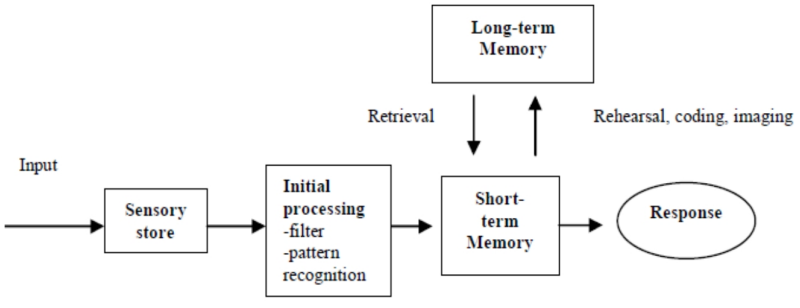

Figure 3.8: Stages of an Information Processing Model by Reed (2009)

Short-Term Memory (STM) gets input from sensory stores. The input is either important or interesting. This memory has the capacity to retain information for up to 20 seconds; however, this time duration can slightly be increased if the information is rehearsed repeatedly. STM can hold up to seven, plus or minus two, items and again this capacity can also be increased if the material is cut up into meaningful parts. There are three possible outcomes of the STM: 1) information may be removed from STM, 2) information may be rehearsed again, and 3) information is transferred from STM to long-term memory. It is therefore important to facilitate students to focus more on important information while separating less important details. Students must be given opportunity to repeat and focus on the information.

Long-term memory (LTM) gets information from STM to store it for longer duration of time and can be recalled again. LTM memory has the capacity to store unlimited amount of information. Rehearsal in the LTM allows repetition of information, and coding is used to semantically represent information which makes it easier to remember and recall. A process of imaging is also used to create visual representation of a word that corresponds to an object; an image is easier to be remembered than words.

Another cognitive theory which is important to be studied is Cognitive Load Theory by (Sweller, 1988). This theory is designed to provide guidelines to assist designers in the presentation of information in a manner that motivates and encourages learner to carry out activities that can lead to increase in performance. According to this theory, contents of LTM are "sophisticated structures that permit us to perceive, think, and solve problems," rather than a group of rote-learned facts. These structures are also

called schemas (Sweller, 1988). These schemas are acquired throughout the lifespan of a person and play a vital role in distinguishing a novice person from an expert person.

2.1.1.3.Constructivism

According to constructivist theory, learner uses their own experience to create and organize information. They need to communicate and collaborate with the social community in order to construct knowledge from the social world. Bruner (1985) shows that children learn new language and other skills not just by learning themselves, but they also learn by having a close interaction with their family members and community. They also gain knowledge and learn while observing others when they are performing certain tasks or skills. It is considered as an active process of constructing new knowledge.

Constructivism implies a new kind of pedagogy in which emphasis is kept on what children do rather than what teachers do. In a constructivist learning environment, a child is given opportunity to organize information and explore them, carry out various activities, and monitor their progress of learning. This theory requires teachers to play a supporting role while the child engages themselves in the problem-solving activities.

2.1.1.4. Discussion

The investigation on the three basic theories of learning; behaviourism, constructivism, and cognitivism which have been discussed in this section, play a vital role in understanding how an individual child absorbs, processes and retains information while they are learning. It is difficult to clearly differentiate one theory from the other in terms of their beliefs and strategies because some of them do overlap. However, several of the significant differences of the theories are listed below:

Behaviourism – learning is organized as a series of activities. Children with ASD can take part in various activities throughout the game. The sequence of responses provided by the children needs to be recorded. Therefore, practicing can allow the children to achieve desired results.

Cognitivism – deals with explaining human behaviours by understanding how learning is processed inside the human brain. The cognitive load of children with ASD needs to be reduced to ensure that these children are able to process information easily; this will improve their performance and increase learning.

Constructivism – is based on the principle that learning involves active processes. Children with ASD take part in different learning activities of the game. From each learning activity, they may encounter new information; they use this information and their experience to construct new knowledge and schemas.

In summary, all three theories: behaviourism, cognitivism and constructivism complement each other as there are principles and strategies among these theories which are interrelated and inseparable. Therefore, the best way to understand and promote learning is to consider the principles and strategies of these theories. The next section discusses the theory of psychology.

3.7.2 Theory of psychology

The earlier sub-section has highlighted all about effective learning of a child. It is also important to understand how a child thinks and behaves during the learning. Therefore, in this section, by understanding the answers of two types of questions (i.e., the how's and the why's of human thoughts and behaviours) better, psychological theory seeks to understand more about the children's (student) learning (Poulou, 2005). This

can be simplified into positive and negative emotions. Eagerness, attention, engagement, pleasure, perseverance, trying hard, and attempting a test, are some of the major causes for positive emotions (Malone, 1980; Preston & Morrison, 2009). While nervousness, feeling unprotected, fear of contest, fear of failure, and inferiority, are some of the leading triggers of negative emotions.

Every user has to handle these emotions while learning through an environment. Fighting the negative emotions, while appreciating and instigating the positive ones can support the user in successful learning. According to Hejdenberg (2005), given the enormous options in the world, making a thoughtful choice between right and wrong is difficult. Therefore, it becomes difficult to see how hard a child works to make the "right" choice. This is why a child always compares their current performance with someone else's, which gives them happiness. The role of serious games comes into play in these situations where, an individual child is free to explore the gaming world and experience these feelings, while competing with others.

Serious games also provide incentives to the users, in the form of rewards, after comparing their performance in the game against their opponents (human or computer). Given the known rules and clarity of instructions, these rewards provide satisfaction and encouragement.

High encouragement in the game boosts the user's confidence; hence, motivating them to achieve higher in all walks of life. This stimulates the positive energy, and suppresses the negative emotions, resulting in better and more successful learning process.

3.7.3 Mapping of game attributes to the theories of learning and theory of psychology

All the discussed game attributes are mapped to the theories of learning and theory of psychology which have been discussed in the earlier sections. The mapping of attributes to the theories are shown in Table 3.9.

Table 3.9: Mapping of game attributes to the theories of learning and theory of psychology

	Behaviourism	Cognitivism	Constructivist	Psychology
Attributes	1. Interaction (equipment) 2. Interaction (interpersonal) 3. Interaction (social) 4. Language or communication 5. Reward 6. Practice and drill 7. Feedback 8. Rules/goals 9. Positive feelings 10. Conflict 11. Debriefing	1. Incremental learning 2. Linearity 3. Attention span 4. Transfer of learnt skill 5. Motivation	1. Scaffolding 2. Learner control 3. Progress 4. Adaptation 5. Location 6. Surprise 7. Help and support	1. Situated and authentic learning 2. Accommodating the learner's style 3. Assessment 4. Fantasy 5. Pieces or players 6. Representation 7. Sensory stimuli 8. Safety 9. Challenge 10. Mystery 11. Intensity

3.8 Summary

The review of frameworks for children with ASD, children, and designing serious games in general were conducted and a number of components were identified from the frameworks. The compiled list of components from these frameworks were processed by grouping similar components together in the intra-frameworks and then in the inter-frameworks. A number of game attributes was identified from the frameworks and related studies. These attributes were based on the theories of learning and theory of psychology; therefore, each attribute was also classified into related theories.

CHAPTER 4: CONSTRUCTION OF SERIOUS GAME DESIGN FRAMEWORK

The aim of this chapter is to present the construction of serious game design framework. It starts by presenting the purpose of the proposed framework followed by the methodology used in the construction of framework. The initial version of the serious game design framework is presented next. For the evaluation of initial version of framework, two expert evaluations followed by an applicability evaluation and applicability survey are discussed next. Lastly, the final version of the proposed serious game design framework is presented after incorporating all the necessary changes in the framework based on the comments provided by the experts.

4.1 Purpose of the proposed framework

The use and success of any serious game developed for children with ASD lies in the design of game. (Hayes et al., 2010) have mentioned in their research that "Children with special needs are increasingly using computers for a variety of tasks and activities. However, designing for children, even those who are neurotypical, can be extremely challenging. Children develop and change mentally, emotionally, and physically at a rapid pace." This indicates that design of serious games for children with ASD can become even more challenging where each child is considered different from one another even though if they have same impairments. Furthermore, they also require one-to-one and specialized set of instruction (Higgins & Boone, 1996; Silver & Oakes, 2001). Therefore, this research attempts to propose and construct a framework that can be used as a basis by the researchers or game designers to design a serious game and facilitate these children in the learning of vocabulary. This specialized framework for the learning of vocabulary caters the need of children with ASD through components from the literature on ASD (sections 2.1 – 2.3 and 2.4 summarized in Table 2.6) and

existing serious games design frameworks (sections 3.2, 3.3 and 3.4 summarized in Table 3.7). The details of components are presented in the sections 4.3.1 – 4.3.3.

4.2 Method

A conceptual or theoretical framework is described as a visual or written narration of the main aspects to be studied in the form of key factors, variables and presumed relations between them (Miles & Huberman, 1994). There are four different ways in which framework can be developed; these include (1) experimental knowledge, (2) existing theory and prior research, (3) pilot and exploratory research, and (4) thought experiments (Maxwell, 2012). In this research, existing theory and prior research is used as a basis to develop a framework for two reasons:

1) This would highlight existing frameworks that have been developed for children with ASD, components used across the frameworks and gaps that can be filled in those frameworks.
2) The review of literature has shown that it is one of the commonly used method. This would also highlight if the existing frameworks would be useful to design game for these children to learn vocabulary, or frameworks needs to be adapted with new components or a new framework needs to be developed.

To develop a serious game design framework, there is a need to perform the following three processes:

1) Identify components that needs to be incorporated in the framework,
2) Identify underlying structure that can used as a basis to develop new framework
3) Logical placement of these components in the identified structure.

The first-two processes are the outcomes of the review of literature, while, the third process uses each component and its purpose from first phase and maps it on the identified structure from the second process. Each of these processes is described in the following sub-sections.

4.2.1 Identification of components

Figure 4.1 shows the literature review sources from chapter 2 that contributed to the identification of components based on the comprehensive review of literature conducted using two systematic literature reviews (SLRs) and five narrative literature reviews (NLRs). The SLRs are represented by the dashed rounded rectangle whereas the NLRs are represented by solid rounded rectangle. An arrow, from one source to another, shows how the review of the current source uncovered more sources to be reviewed. The review of literature started with the first SLR on 'strategies and CBIs' which uncovered three sources to be reviewed further, from which the second SLR was conducted on modalities while the NLRs were conducted on the other two sources. The review progressed further from the second SLR to other sources on which NLRs were conducted as shown in the figure. Table 4.1 presents all the components gathered from the review of sources shown in the Figure 4.1; the table also presents the purpose of each component in the framework, and the sources used to gather their details.

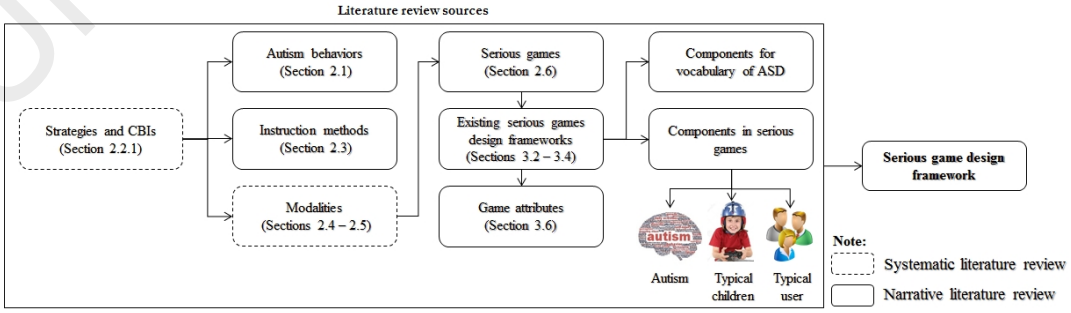

Figure 4.1: Literature sources used for the identification of components

Table 4.1: Components, their purpose in framework, and the sources used to gather their details

Component	Purpose	Sources
Autism behaviours	Intervention of behaviours	(Rocky Point Academy, 1997; Centers for Disease Control and Prevention [CDC], n.d.; Association, 2000; Bosseler & Massaro, 2003; Johnson, 2004)
Instruction method	Effective intervention	(National Autism Center 2009)
Strategies	Motivation and focused learning	(Khowaja & Salim, 2013)
Modalities	Alternate ways of interaction with system	(Basil & Reyes, 2003; Bosseler & Massaro, 2003; O. E. Hetzroni & Shalem, 2005; O.E. Hetzroni & Tannous, 2004; Massaro & Bosseler, 2006; Moore & Calvert, 2000; Whalen et al., 2010)
Capabilities	Develop skills	(Yusoff, 2010)
Instruction contents	Provide subject matter	(Garris & Ahlers, 2001; Yusoff, 2010)
Learning outcomes	Define goals	(Garris & Ahlers, 2001; Yusoff, 2010)
Learning activity	Engaging activities	(Yusoff, 2010)
Game genre	Categorize activities	(Yusoff, 2010)
Game mechanics	Rules and regulations	(Winn, 2008) (Yusoff, 2010)
Game dynamics	Emergent behaviour	(Winn, 2008) game websites
Game story	Develop story	(Winn, 2008)
Storytelling	Designers' & player's story	(Winn, 2008)
Narratives	Written or spoken words of designers' story	(Winn, 2008)
Characters	Artificial intelligence based non-playing characters	(Winn, 2008)
Game attributes	Validate learning as done in classroom environment	(Garris & Ahlers, 2001; Yusoff, 2010)
Reflection	Improve thinking	(Yusoff, 2010)
User profile	User details	(Yusoff, 2010)
User achievements	User performance	(Yusoff, 2010)

As discussed in section 2.7 of chapter 2 on existing serious game frameworks, (Winn, 2008) has described the heart of serious games as shown in Figure 4.2 which require consideration of components from three different perspectives, namely theory, content, and game design.

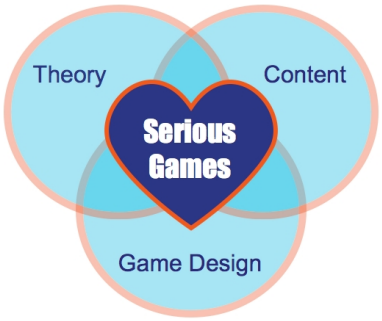

Figure 4.2: Heart of serious game design by Winn (2008)

In the context of this research, the components from the perspective of ASD are also considered. This leads to the heart of serious game design for children with ASD as shown in Figure 4.3 with an additional perspective of ASD. The figure shows the mapping of all the components from Table 4.1 to the four perspectives. Following are brief descriptions of each perspective from the context of ASD:

- Theory represents all the relevant theories that can contribute to the design of serious games for these children. Theories of learning and theory of psychology as discussed in sections 3.7.1 and 3.7.2 can also be used in the design of serious games for these children. Both of these theories are covered by the component named 'game attributes' from Table 4.1; therefore, this component contributes from the perspectives of theory in the design of serious games for children with ASD.
- Contents represent the subject-matter to be taught to an individual child with ASD; in this research, the subject-matter related to the learning of vocabulary is represented as contents. The four components from Table 4.1 namely capabilities, instruction content, learning outcomes, and reflection contribute from the perspectives of contents in the design of serious games for these children.
- ASD represents the key components to be considered from the ASD perspective to support in the design of serious games related to learning of vocabulary. The four components from Table 4.1 namely autism behaviours, strategies, instruction

method, and game modalities contribute from the perspectives of ASD in the design of serious games for these children.

- Game design comprises of all the components that contribute to the design of serious games for these children. The ten components from Table 4.1 namely learning activity, game genre, game mechanics, game dynamics, game story, storytelling, narratives, characters, user profile, and user achievements contribute from the perspectives of game design in the design of serious games for these children.

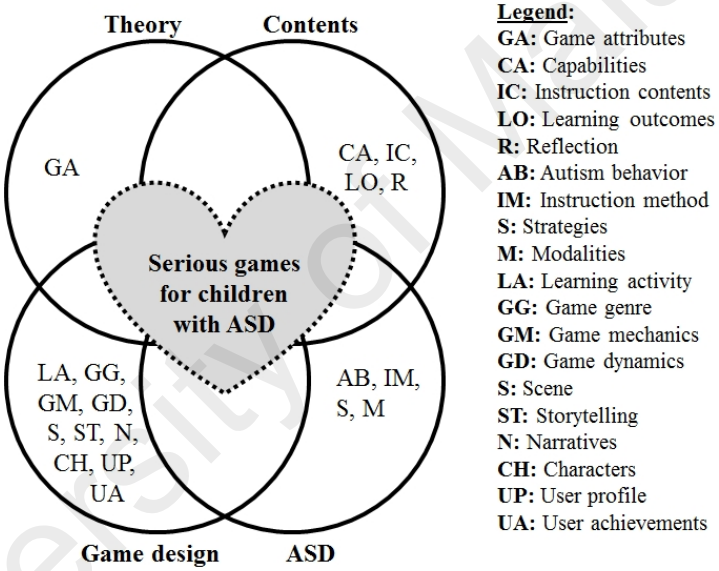

Figure 4.3: Heart of serious game for children with ASD

4.2.2 Identification of structure

In sections 3.2 – 3.4, six existing serious game design frameworks were reviewed. The three frameworks by (Park et al., 2012), (Annetta, 2010) and (Obikwelu & Read, 2012) have a specialized structures that makes them difficult to adapt for the development of another framework. It is because the structures only support design of games for certain skills or it only considers certain aspects of selected theories to design games which limits their usefulness. The remaining three frameworks by (Garris et al.,

2002), (Winn, 2008) and (Yusoff, 2010) have a structures that can be used to develop new framework. From these three framework, the structure based on input, process, output (IPO) model proposed by (Garris et al., 2002) is selected for the development of framework in this research for three reasons: 1) use of IPO in the development of other frameworks, 2) use of IPO in the development of game, and 3) use of similar process in the research of ASD. These reasons are further discussed below:

1. Use of IPO in the development of other framework: The forward searching technique was used to further analyse the extent to which IPO is used by the researchers. It was found that a lot of researchers have used an input, process, output (IPO) model proposed by (Garris et al., 2002) as a basis to propose or develop framework for serious games. It was also found that a framework by (Yusoff, 2010) reviewed in the section 2.7 has also used IPO model as a basis to develop its framework of serious games.
2. Use of IPO in the development of game: IPO is considered as a generic framework as it allows researchers to develop different games based on two aspects: 1) types of outcomes to be achieved and 2) contents to be learned through game. The successful pairing of instructional contents and game attributes can result in repetitive and self-motivating gameplay. The input phase comprise of these two aspects and the identification of game attributes that needs to be incorporated in the game. The key of IPO model resides in the process; a central hallmark of game is not that users plays it once and leave it aside but it should generate motivation to keep on playing over and over again. The output validates the performance of user against the objectives of game; this indicates the overall success of playing game. The structure of IPO model depicts learning process used in game where user selects the content to learn as an input, undergoes rigorous sub-process of learning by taking part in the

different activities where assessment is also conducted to evaluate the learning in the user; the result of assessment determines the rate of achieving the expected learning outcomes.

3. Use of similar process in the research of ASD: Additionally, the review of studies on intervention for children with ASD have also highlighted that a similar (IPO) learning process is used in the interventions of these children. The selection of contents varied from one research to another. In (Bosseler & Massaro, 2003; Massaro & Bosseler, 2006), for instance, child either selected the contents to learn at their own or was guided to perform this selection. However, there were studies in which contents to teach were very limited for instance (L. C. Mechling & Ortega-Hurndon, 2007); therefore, instead of allowing child to make a selection of what to learn, the contents were taught in the order chosen by the researchers. Regardless of content selection, child was provided motivated and focused learning environment and went through the short drill and practices on continuous basis to monitor their performance over the period of time. These practices and a follow-on test towards the end of learning indicated the overall outcome of learning in child.

4.2.3 Logical placement of components in structure

Each component identified in sub-section 4.2.1 needs to be logically placed in the phases of IPO model identified in the sub-section 4.2.2; this is to ensure that both the structure of framework and the components are synchronized with that of IPO by (Garris et al., 2002). The placement is done based on the purpose of each component as described in 4.2.1 and the mapping of components to the model by Garris. The phases of IPO model, their purpose and the logical placement of all the components is shown in Table 4.2. It can be seen that input comprise of fours component (autism behaviours, capabilities, instruction contents, intended learning outcomes). The process comprises

of thirteen components (instruction method, strategies, modalities, reflection, learning activity, game genre, game mechanics, game dynamics, game story, storytelling, narratives, characters, game attributes). The output contain two components (user profile and achievements).

Table 4.2: Logical placement of components in the phases of IPO model

Phase	Purpose	Components
Input	Contents for intervention of behaviours	autism behaviours, capabilities, instruction contents, intended learning outcomes
Process	Learning activities	instruction method, strategies, modalities, reflection, learning activity, game genre, game mechanics, game dynamics, game story, storytelling, narratives, characters, game attributes
Output	Debrief and save user performance	User profile and achievements

4.3 Serious game design framework

The information presented in the sections 4.2.1 through 4.2.3 is used as a basis for the development of serious game design framework. Figure 3 shows the serious game design framework based on the identified structure of IPO and the twenty components logically placed into input, process and output of the structure using components presented in The information presented in the sections 4.2.1 through 4.2.3 is used as a basis for the development of serious game design framework. Figure 4.4 shows the serious game design framework based on the identified structure of IPO and the twenty components logically placed into input, process and output of the structure using components presented in Table 4.2. The following sub-sections describe all the phases of IPO and the components associated with it.

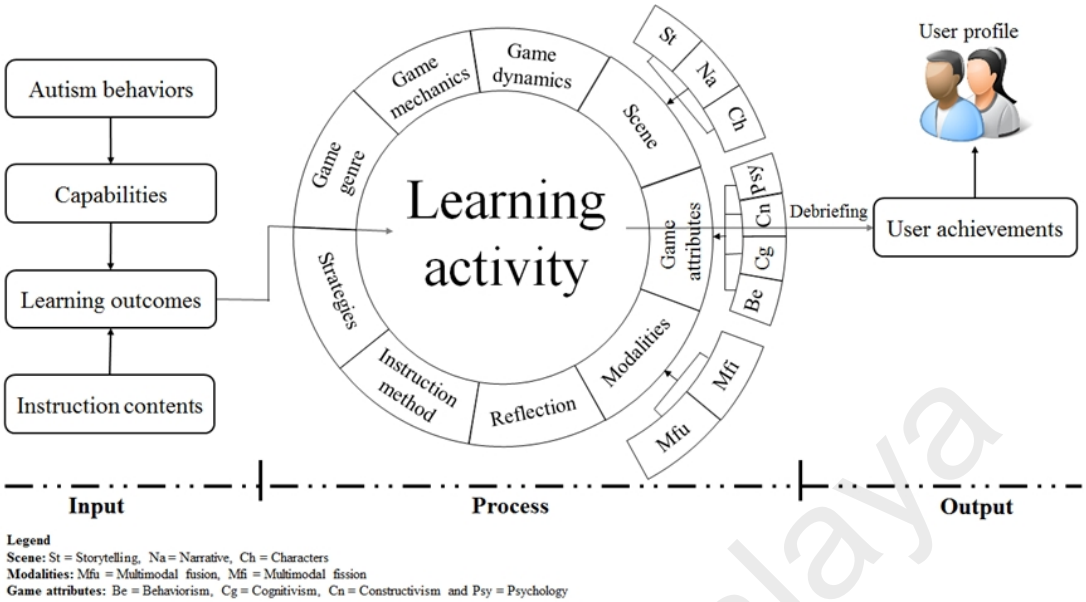

Figure 4.4: serious game design framework for children with ASD

4.3.1 Input

The input refers to the data process that identifies the behaviour related to the vocabulary in which children with ASD face difficulties, objectives that needs to be achieved and accordingly the appropriate contents for these children with ASD to learn and improve the behaviour related. Following are the components and their description of components in this phase:

4.3.1.1 Autism behaviour

Each child with ASD possess different set of behaviours. Before the game design process begins, it is important to identify the behaviours that needs to be targeted in the serious game. The selection of these behaviour will help in the selection and creation of appropriate instructional contents and learning activities. Section 2.1 has highlighted different behaviours related to ASD which have been classified into language comprehension, verbal communication, non-verbal communication and general behaviours.

4.3.1.2 Capability

Capability refers to the development of one or more of three types of skills namely cognitive, psychomotor and affective skills that player of the game can develop as a part of playing game (Yusoff, 2010). The cognitive skills have been identified based on the cognitive domain of Bloom's taxonomy (Bloom, 1971), psychomotor domain of Dave's taxonomy (Dave, 1970) is used to identify psychomotor skills and affective skills are identified based on the affective domain of Krathwohl's taxonomy (Krathwohl, 2002).

Cognitive skills refers to the development of thinking ability in the players which they can use to solve problems of varying degree i.e. from easy to difficult either as a part of learning activities or the evaluations following learning of contents through game (Bloom, 1971). The categories of cognitive skills have been drawn from the Bloom's taxonomy which include recall, understand, apply, analysis, synthesis, and evaluation.

The psychomotor skills have not been categorized by the Bloom and his colleagues, however, there are other researchers who have categorized the skills and created their own psychomotor taxonomies. These include Simpson's psychomotor domains (E. Simpson, 1971), Harrow's psychomotor domains (Harrow, 1972) and Dave's psychomotor domain (Dave, 1970), however, the categorizations by the Simpson and Harrow are useful for the development of this skill from the children to adults.

Table 4.3: Categorisation of psychomotor skills by various researchers

Sources	Categorization
(E. Simpson, 1971)	1) perception (awareness) 2) set 3) guided response 4) mechanism (basic proficiency) 5) complex overt response (expert) 6) adaptation

	7) origination
(Harrow, 1972)	1) Reflex movement 2) fundamental movements 3) perceptual abilities 4) physical abilities (fitness) 5) skilled movements 6) no discursive communication
(Dave, 1970)	1) imitation 2) manipulation 3) precision 4) articulation 5) naturalization

(Krathwohl, 2002) has developed a taxonomy for the affective domain which include five categories, namely, receiving, responding, valuing, organization and value complex.

4.3.1.3 Intended learning outcomes

The intended learning outcomes are the overall goals that needs to be achieved by playing serious game. Each of these objectives are created based on the combination of specific capability to be achieved in the user as well as specific instructional contents. Each learning activity to be incorporated in the games should have at least one learning outcome. These outcomes are decomposed into all the activities of the games based on the overall instructional contents to be learnt by players. This way, players know in advance what needs to be accomplished and what to expect from the material to be learnt within a specific activity. According to the pedagogical guidelines, these learning outcomes should be communicated to the user and this is typically shown at the introduction of the serious game and also available through the help menu of the serious game. These pedagogical guidelines are based on the Gagne's nine events of instruction (Gagne, 1985).

4.3.1.4 Instructional contents

The instructional contents refers to the specific contents or subject matter that player can learn through the serious game. The categories of instructional contents and specific contents supported by the serious game could be an exhaustive list. According to (L. Gilbert & Gale, 2008), there are four different types in which contents can be classified, namely, facts, concepts, procedures, and principles. Each of these types are briefly described below.

Fact: it is a statement that is true or real; it could also refers to something that can be shown to be real or true. It consists of two specifics 'A' and 'B' so-called fact pair about something; these specifics could refer to definition, name or number. For instance, one litre of milk weighs one kilogram or Malaysia is a federation consisting of thirteen states (Negeri) and three federal territories (Wilayah Persekutuan).

Concept: means basic understanding about something that is necessary to make sense out of it. This type of learning is typically based on values, ideas, symbols, events or things that are associated with it. A concept has name 'X', a superordinate class 'Y' of which X is a member and a list of attributes 'An' and values 'Vn' where 'Vi' corresponds to 'Ai.' These attributes serve a purpose to classify or sort objects of different types. The use of phrase 'is a' distinguish a concept from that fact. For instance, 'an apple' is a 'fruit' and list of attributes could be 'colour', 'weight' and 'country of origin', 'taste' among others.

Procedure: refer to learning how to step-by-step perform sequence of actions to accomplish a task. A procedure typically has a name 'X' and it is used in some situation 'S' to achieve goal 'G' using set of steps 'E' by using some tool 'T'. For instance, to eat a pomegranate, a person first Cut off its crown with a sharp knife, then score the

pomegranate with cuts as if you are going to break it into quarters, then soak it in cold water as it allow seeds to be easily collected. While the pomegranate is under water, gently pull pomegranate apart into quarters then run your fingers through each quarter slice to start separating the seeds.

Principles: refers to a propositions which contains a name 'X', is applied in a situation 'S' and involves the specification of cause-effect relationships (CERs) between objects or events 'E'.

4.3.2 Process

Process refers to the process of using data from the input phase and developing one or more learning activities that meets all the identified objectives. The key of IPO model used in this research resides in the process; a central hallmark of the game is based on the design of activities that keep children motivated through interactive medium of learning instructional contents that can increase their interest level to play game over and over again. Each activity needs to address one or more of the learning outcomes to ensure that child would be learning the same contents and also facilitate in the same capabilities as identified in the input phase. The components in this phase were classified based on the description of process from section 4.2.2. The components that facilitate in designing learning activities are described as follow:

4.3.2.1 Reflection

Serious games typically consists of a set of inter-related learning activates where each activity builds on top of previous activity in terms of difficulty level of an activity. Reflection is about giving an opportunity to the player to think about reasons behind undertaking the current learning activity. This thinking process is based on all the learning activities that player has performed since it started playing the serious game.

This allows player to understand and identify the skills and approaches used to solve similar problems in the previous activities and identify the approaches and skills need to solve problems in the current activity.

This process can be facilitated by providing information to the players towards the end of each activity about: 1) the current activity undertaken, 2) their achievement in the activity and 3) the objectives accomplished through the activity. This information could be useful for the player as otherwise they may forget the actual objective behind the current activity. (Garris et al., 2002) have also recommended the similar set of information to be provided to the player. The set of information include: 1) description of the current activity undertaken, 2) purpose behind undertaking the current activity, 3) all the errors made throughout the activity, and 4) suggestions on how to correct those errors. According to (Simon, 1979), Kolb's problem solving cycle can also be used to support player's learning based on the reflection. This cycle includes four steps that be incorporated in the learning activity; these steps include doing, reflecting, understanding and applying.

4.3.2.2 Instruction method

Instruction methods for ASD are the evidence-based methods that have proven to be effective for some individuals on the spectrum. There is no universal method as such which has proven to be the most effective method for all the children on spectrum. The use of instruction methods in the intervention for these children highly depends on the skills targeted in the intervention. The skill targeted throughout this research is the vocabulary of these children and section 2.3 has highlighted five different instruction methods that can be used to provide intervention of vocabulary in particular or language in general.

4.3.2.3 Strategies

Strategies are the techniques which facilitate instructors to get the attention of children, stimulate their interest towards the learning of contents, keep them engaged in the learning process, develop their thinking skills and increase interaction so that they remain focused on the learning. The strategies can also be used to connect idea to the real-world which can provide opportunity to these children to generalise the contents are one situation to another. These strategies are used to support instruction methods for ASD.

4.3.2.4 Learning activities

Learning activities are the set of activities designed to keep players actively involved when they are playing the games. The effective design of these activities ensures that players stay engaged and immersed without getting bored. Another important aspect is to ensure that the learning material used is appropriate and challenging for players who are seeking improvement in their competency slightly above their current level of competency (Gee, 2007). These activities make use of the material from the instructional contents to be used throughout the game.

4.3.2.5 Game genre

Genre is used to categorise games based on the interaction between the players' so-called gameplay rather than differences in visual or narratives. It is defined by a set of gameplay challenges. These genres range from action, adventure to a combination of action-adventure, role-playing, simulations, strategy, and sports among others.

4.3.2.6 Game mechanics

Game mechanics are a set of actions, behaviours and control mechanisms given to a player within the context of a game (Hunicke et al., 2004). These mechanics are used to

define a rule-based system for the game environment by specifically stating all the objects that would available within the game environment, how each object would behave, and how user can interact with them in the game world.

4.3.2.7 Game dynamics

Game dynamics refers to the change that occurs in the gameplay when the game mechanics are activated within the environment of the serious game. This provides more fun, enjoyment and engagement in the games for the player. Assume user is playing a time-based game where user needs to collect specific fruits falling from trees (placed at different horizontal location with varying height) in the basket before they touch the ground. These fruits are mixed with other fruits that act as a distractor and user is penalized for catching one of the distractors. Both, the actual and distractor fruits fall at the same constant speed until the time of 30 seconds remain where the gameplay changes as the speed is increased by twice and the penalty factor is also doubled.

4.3.2.8 Game story

The overall story of the game consists of one or more of the three components i.e. storytelling, narratives and the characters involved in the game. These three components of the game story are described in the following sub-sections.

(a) ***Storytelling***

Human beings are very good in storytelling; they tend to describe the situation to others exactly the way they perceive it. They are also good at seeing them well. The perception of stories is based on the experience of an individuals and how they understand their world and the surroundings. The storytelling in a serious game can in two different forms: 1) designer's story, and 2) player's story (Rouse III, 2010). The designer's story highly depends on the integration of various aspects related to the

serious game i.e. context in which serious game is to be played, instructional contents to be learned by the user, scenes to be created, how characters, narratives are synchronized with each other across the scenes among others. The resultant story is incorporated inside the serious game. The storytelling that user experience while playing serious game is based on the designer's version of story as well as all the interactions and the selections made by the user itself throughout the serious game. The overall resultant experience becomes the player's own version of story and it is least likely that the stories of two players would be the same. The use of designer's story highly depends upon the game genre of the serious game i.e. their story is strongly used in the adventure or role-playing games whereas in the game genre like logic or board games, it is possible that designer's story is least used or not used at all. However, each serious game does include player's version of story which at the minimum include all the activities played and the challenges performed throughout the game. It is at the discretion of the game designer to decide which type of story should be experienced by the user of the serious game.

(b) ***Narrative***

A narrative refers to one of the story events presented to the player within the game world (Adams, 2010). It consists of a non-interactive presentational material either in the form of text only or a combination of text, audio and animation shown to the user as a part of narration. The purpose of narrative is to present an event which cannot be controlled or interacted by the user. Narrative is typically used to establish the setting of an environment in which player would play game provide initial motivation towards the game, but often, it is not the main focus of game play. They are also shown when user moves from one scene to another, towards the end of level when user has accomplished the goals or towards the end of the game as well.

(c) ***Characters***

These characters represents all those characters in the game which are instead of being controlled by the player itself are controlled by the artificial intelligence (AI). These characters are also referred with different terms including nonplayer characters (NPCs), nonperson characters (NPCs) or nonplayable characters (NPCs). The role of each character used within the serious game may vary from one another. They may be used to provide support to the user whenever they are stuck within the game environment and not sure what to do next. They can be part of your user's team in a strategy based game to support you in achieving your goals or they can even be in the opposite team as your enemy. These characters can also play a role of some random character who is freely moving around within the game environment and may or may not have an ability to interact with your character when both are next to each other.

4.3.2.9 Game attributes

The learning through serious games needs to be validated against current teaching practices to ensure it is at the same level as that of traditional classroom learning. Therefore, it is important to incorporate certain aspects of current teaching practices in serious games that have proven to be successful in the classroom. These successful aspects are referred to as game attributes. These attributes support learning and engagement throughout the game; this allow users to remain active and think critically while learning and playing games. These attributes are based on different theories namely behaviourism, cognitivism, constructivism and theory of psychology. Section 3.7.3 shows list of all the attributes and their classification into one of the four mentioned theories.

4.3.2.10 Modalities

Modality acts as a channel of communication between the user and the computer (more precisely, the serious game in the context of this research) itself (Nigay & Coutaz, 1993). It can be used to convey some information to the serious game or acquire some information from the serious game in return. Games that make use of just one modality are known as unimodal, whereas, games in which two modalities are used are known as bimodal. Finally, games that integrate more than two modalities are known as multimodal games. The combination of two or more modalities for input is known as multimodal fusion. Likewise, the partitioning of information into two or more communication modalities is also known as multimodal fission. Examples of input modalities include speech, gestures, gait, facial expression among others, whereas, text, graphics, animation, video model, virtual character, and force feedback are few examples of output modalities.

4.3.3 Output

Output focuses on the user profile and the debriefing of the all events that would happen as child plays game. Each learning activity from the earlier phase is taken into consideration for the development of user profile and to ensure that all essential information related to user performance in the activity is retained in the profile. The overall outcome of following through all three phases of IPO model reveals an integrated design and all the necessary details of a serious game for children with ASD to learn vocabulary. The components of output are described below:

4.3.3.1 User profile and achievements

Game must allow users to set up their own profiles that contain their basic information. Once created, this profile will be updated regularly with all the

accomplishments as users progress through various activities of the games. This way, users can also look back at all the achievements. It can also allow them to practise one of the previously learnt skills to improve their learning. Achievement in the games can be shown in the form of scores, total number of resources gathered in the games, or the time taken to accomplish that task.

4.3.3.2 Debriefing

It has been seen that, user always expects to be notified about how well they performed throughout the game. Debriefing plays an important role in the serious games to improve the overall learning and experience of user. The use of debriefing or post experimental analysis in the educational setting has been first reported by the (Lederman, 1984). The debriefing was first used in the simulation or game. The purpose of debriefing is to provide a review of all the activities in which user took part while playing game. For each activity, this review may provide description of the activity performed, their performance in the activity, highlighting all the incorrect responses as well as the correct responses that should have been selected. The designer needs to take into consideration how to display all the information so that user does not feel overloaded and can easily concentrate on the corrective actions that needs to be taken.

4.4 IPO-based frameworks to design serious games

Section 4.2.2 has highlighted the wide applicability of IPO in the construction of serious games design frameworks. In this section, two frameworks constructed based on IPO structure are shown in Table 4.4: i) the serious games design framework proposed in this research specific for children with ASD to learn vocabulary, and ii) the serious games design framework in general by (Garris & Ahlers, 2001).

The IPO details (i.e. information gathered and outcomes) of the framework constructed in this research (i.e. second column) are based on the components identified from the extensive review of literature on ASD and existing serious game design framework for ASD, typical children and typical users. The IPO details of framework by (Garris & Ahlers, 2001) are generic and from the perspective of game design in general i.e. irrespective of any specific user.

Table 4.4: IPO-based serious game design frameworks

Phases of IPO	**Serious game design framework proposed in this research**	**Serious game design framework by (Garris & Ahlers, 2001)**
Input	1) **Information gathered:** Intervention of behaviours 2) Objectives to be achieved 3) Contents to be learned 4) Capabilities to be developed **Outcome:** Objectives to be achieved in the learning activities	1) **Information gathered:** Contents to be learned 2) Game attributes to be incorporated **Outcome:** Contents and game attributes to create game cycle
Process	**Information gathered:** 1) Learning activities to be developed 2) Components that constitute each learning activity 3) Identify game attributes to be incorporated in the game; motivation and other elements that derives the process of Garris are part of it. **Outcome:** Learning activities	**Information gathered:** Game cycle based on user judgment, user behaviour and system feedback **Outcome:** Game cycle
Output	**Information gathered:** 1) Use profile to save performance of learning activities 2) How to provide debriefing 3) How to validate performance against objectives of game **Final outcome:** Design of a serious game to	**Information gathered:** 1) How to provide debriefing 2) How to validate performance against learning outcomes of game **Final outcome:** Design of a game for typical users

	provide intervention of identified behaviours related to vocabulary of children with ASD	

4.5 Evaluation of the proposed framework

The initial version of the proposed framework was thoroughly evaluated through multiple methods of evaluation which include expert review studies, an applicability test and applicability survey. The methods used and the outcome produced throughout the evaluation are shown in Figure 4.5. First, an expert review study was conducted to evaluate the initial version of the framework from the perspective of academicians. The changes recommended by the academicians were incorporated in the framework which lead to improved version of the proposed framework. Another two studies were conducted to evaluate the framework from the collective viewpoint of two different types of experts including researchers working on serious games and game designers. First, an expert review study was conducted; second, an applicability test was conducted to assess the application of the framework followed by a survey to gather feedback regarding applicability of the framework. The changes recommended by the experts from the first study were incorporated to produce modified version of the framework. This version of the framework was used in the second study as a part of its applicability. The proposed version of the framework was produced based on the comments provided by the experts of second study.

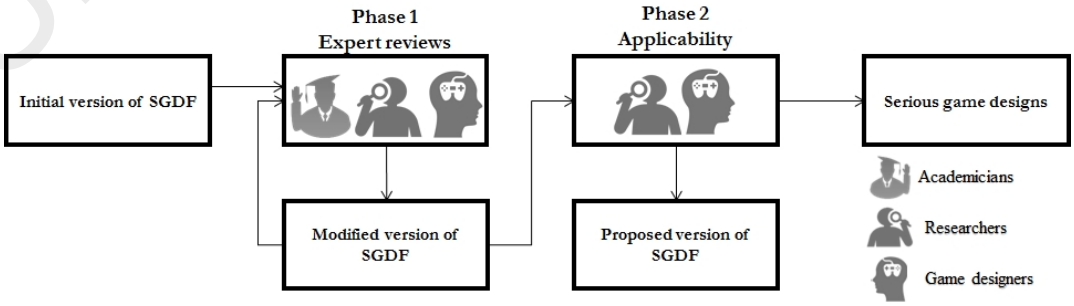

Figure 4.5: Methods and flow of evaluations of the proposed framework

Table 4.5 through Table 4.7 presents the GQM statements to perform the expert review studies, and applicability test.

Table 4.5: GQM statement to perform expert evaluation with the academicians

To analyse	the components used, their usefulness in the framework, relations between components, structure of the proposed framework
in order to Evaluate	the framework to design serious game for the vocabulary acquisition of children with ASD
from the perspective of	the academicians working in the field of serious games
in the context of	face-to-face discussion and survey based questionnaire
because	these experts either design, use or evaluate such framework on a regular basis. Therefore, their expert opinion is used to improve proposed framework

Table 4.6: GQM statement to perform expert evaluation with the game designers or researchers

To analyse	the components used
in order to evaluate	the framework to design serious game for the vocabulary acquisition of children with ASD
from the perspective of	the two types of experts including game designers or researchers working in the field of serious games
in the context of	face-to-face discussion and survey based questionnaire
because	these experts are the ones who work with these components during the design of serious games in real-life. Therefore, their input is taken to improve proposed framework

Table 4.7: GQM statement to perform applicability test with the game designers or researchers

To analyse	the application of the serious game design framework to design serious game for the vocabulary acquisition of children with ASD.
in order to assess	With respect to: Understandability Learnability Adaptability Usability Memory load Expectations Usefulness Complexity Development Willingness
from the perspective of	the game designers or researchers working in the field of serious games
in the context of	Survey based questionnaire
because	the practical use of framework to produce serious game design by the potential users can help to improve the framework in terms of aspects assessed in the study

4.6 Expert evaluation 1 with academicians

This section describes the recruitment process of the participants, the instruments used, the reviews procedures carried out, and lastly the analysis of results are presented which lead to the improved version of the proposed framework.

4.6.1 Participants and recruitment

The academicians working in the area of serious games were invited to part in this study. The selection of these experts was carefully done using Google Scholar[7] and ResearchGate[8], and Google[9] search engine. The experts were also asked to provide recommendations of other experts who can be invited to take part in this evaluation. The invitation to take part in the expert review study was sent to a number of participants from which 9 experts showed their willingness through positive acknowledgement and

[7] https://scholar.google.com
[8] http://www.researchgate.net
[9] https://www.google.com

took part in the study. The demographic information of participating experts is shown in Table 7.

Table 4.8: Academic experts' demographic information

Id	Gender	University	Country	Research interest	Experience
1	Female	Murdoch University	Australia	Educational technology	20 years
2	Male	Curtin University	Australia	Game-based learning, Complex systems, digital media learning and psychometrics	30+ years
3	Male	VU University Amsterdam	Netherlands	multimedia & game technology, interactive video, serious games	20+ years
4	Male	Birmingham City University	United Kingdom	Serious games and real and virtual educational robotics for secondary and tertiary mathematics education	9 years
5	Male	NHL University of Applied Sciences	Netherlands	Serious Gaming: a systemic approach; health and wellbeing; vocational safety; social innovation	4 years in serious gaming; 20+ years in research
6	Male	Charles University in Prague	Czech Republic	game-based learning; artificial intelligence for computer games; computational ethology; computational neurobiology	10 years
7	Male	RMIT Europe	Spain	game design, user experience, play	15 years
8	Male	Coventry University	UK	Games Science (Serious Games, Gamification), pervasive learning, simulation	10 years
9	Male	University of Ottawa	Canada	Gaming Systems and networks	30 years

4.6.2 Instruments used

A questionnaire which consists of four parts and comprising a combination of close-end and open-ended questions was prepared to gather feedback from the experts. The

purpose of each part and type of questions asked in it are described in Table 8 while the structure of the questionnaire is shown in Figure 4.6 and complete questionnaire is available in Appendix D. All close-ended questions in the survey are based on 3-points Likert scale ('Disagree', 'Not sure' and 'Agree').

Table 4.9: Details of parts and questions in questionnaire

Part	Purpose	Questions
Part B	**Heading: Importance, description and details of components, and their adequacy (missing, removing) of components used in the proposed framework** **Details:** To get feedback on the importance of each component in the game, determine if the description is readable and the details in description are sufficient or require more information to be added and if there are component that needs to be removed from or added to the framework.	close-ended questions and comments or suggestions
Part C	**Heading: Structure of the framework** **Details:** To validate the logical division of components to the three phases corresponding to input, process and output of IPO and the structure of framework.	close-ended questions and comments or suggestions
Part D	**Heading: Relations between components** **Details:** To ascertain whether the relations between components are logical or they needs to be fixed and to determine the missing relations (if any) so that framework can be improved accordingly.	close-ended and open-ended questions
Part E	**Heading: Comprehensiveness of the framework** **Details:** To get suggestions or recommendations for the improvement of framework.	open-ended question

The first level in Figure 4.6 shows the shorter name from the headings of four parts i.e. part A to part D mentioned in Table 4.9 while the second levels onwards shows the questions and sub-questions in each part. Each part contains at-least one qualitative question for expert to provide their descriptive responses regarding questions asked in that part.

Part A contains same set of questions (Q1, Q1a to Q1c and Q2) for each component of the framework; the twenty one components of framework are represented through numbers from Co1, Co2 up to Co21. The question number in plain text indicates that

it's a quantitative question while the bold and underlined question number represents a qualitative question. Altogether, this part contain 84 quantitative and 23 qualitative questions.

Part B comprises of four sub-parts; input, process and output are related to the phases of framework while IPO correspond to the structure used in the framework. Altogether, this part contain 23 quantitative as well as 3 qualitative questions.

Part C consists of 6 quantitative as well as 3 qualitative questions related to the relationships between components.

Part D is related to the comprehensiveness of the framework and consists of just one qualitative question.

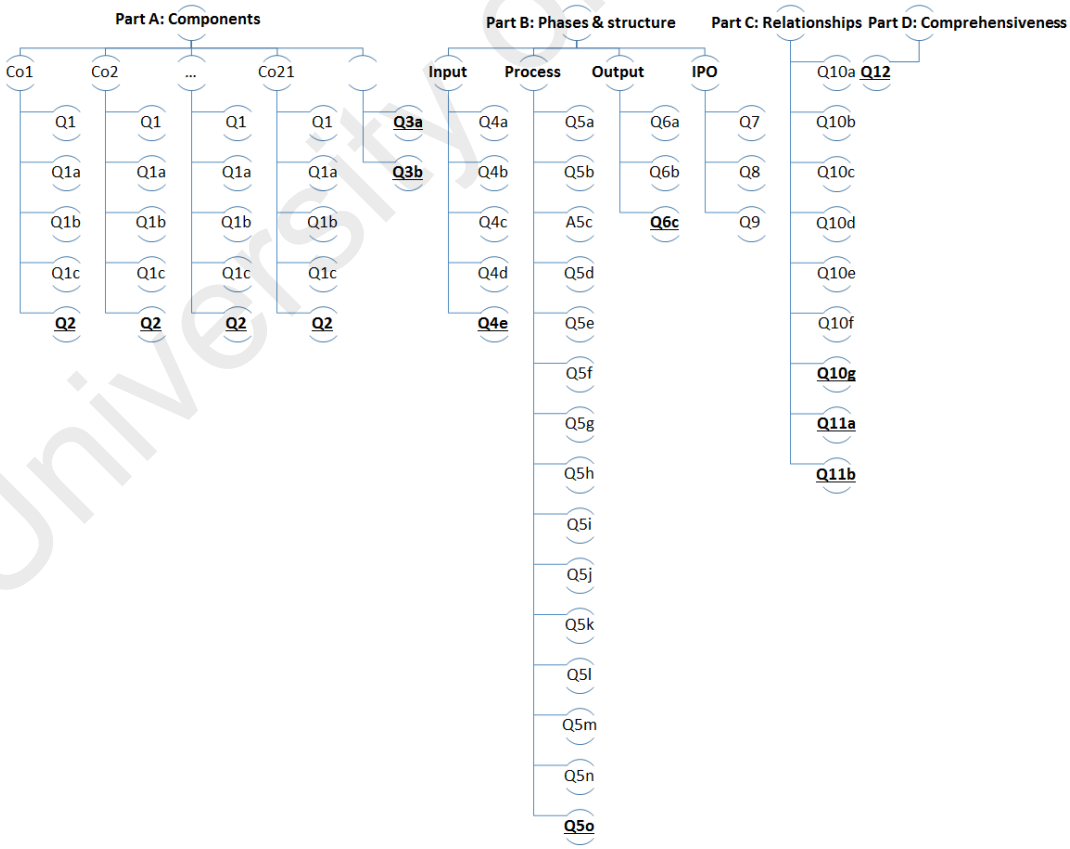

Figure 4.6: Structure of the survey questionnaire

4.6.3 Study protocols

Each expert was independently invited through an email to take part in this review study; the expert who positively acknowledgement the invitation was sent two files through an email to perform evaluation: the first file included framework and descriptions of all the components, while the survey questionnaire was included in the second file. An online Skype session was conducted with the participants at their time of convenience to brief about the background of study, its objectives, introduction to the serious game design framework and its components and answer any of the queries related to the framework or survey questionnaire sent earlier. The comments given by the experts during the session were noted and the experts were also informed to specify the same comments as a part of their evaluation. However, there were certain cases in which it was not possible to hold a Skype session for different reasons which include tight schedule of an expert, restriction to use Skype in the premises of their university or the time differences among others. In such cases, experts were informed to email details of any query related to the framework or survey questionnaire.

4.6.4 Data analysis

4.6.4.1 Quantitative analysis of the frequencies of opinions

The data provided by the experts in response to close-ended questions was analysed by using the frequency of responses in relation to the 8 questions and their sub-questions (Q1, Q1A – Q1C, Q4A – Q4D, Q5A – Q5N, Q6A – Q6B, Q7, Q8, Q9, Q10A – Q10F) of Part A, B, and C as shown in Figure 4.6. The frequency for these questions and sub-questions was calculated as a cumulative sum of responses for ‘disagree’, ‘not sure’ and ‘agree’.

4.6.4.2 Qualitative analysis of descriptive response

(Seaman, 1999) has presented several qualitative methods for the data collection and analysis. One of the methods explained by the author for the analysis of qualitative data is to identify categories that can help in the classification of descriptive responses by experts for the further analysis. This technique is also used in this review study for the analysis of responses provided by the experts.

Each response provided by the experts in 7 questions and sub-questions Q2, Q3a – Q3b, Q4e, Q5o, Q6c, Q10g, Q11a – Q11b, Q12 of Part A, B, C and D as shown in Figure 4.6 is to be classified into four categories: suggestion, concern agreement or disagreement. The description of these sub-categories are: 1) suggestion is some sort of action required to make necessary changes in the proposed framework; 2) concern by an expert that require attention 3) agreement is the acceptance on the game components or connections between them which does not require any change to be made in the serious game design framework and lastly 4) disagreement is the concern raised by an expert on the serious game design framework and require attention.

4.6.5 Results

4.6.5.1 Frequency of the opinions provided by the experts

This section presents the results of the quantitative questions (section 2.4.1) in the form of cumulative frequencies of responses. The responses for components in the input, process and output phases of framework from the questions of Part A are shown in figures 4, 5 and 6 respectively. For each component, four results are shown: 1) 'I' for importance of component from Q1, 2) 'U' for use of component in design from Q1a, 2) 'R' for readability of description from Q1b and 4) 'D' for sufficient details in description from Q1c. Each figure shows 3 lines of which red line or line with triangle

markers indicate number of those experts who selected ‘disagree’ as their answer to the question, experts who mentioned ‘not sure’ as an answer are represented by blue line or line with square markers, while, green line or line with circle markers include number of experts who responded ‘agree’ to question. The cumulative sum could indicate that most of the experts have: 1) agreed with the information asked in the question, 2) disagreed with the information asked in the question, 3) not sure about the information asked in the question, or 4) mixed opinion with the information asked in the question which means sum of the experts who selected agree is almost same as of sum of the experts who either selected disagree or not sure.

*(a) **Part A – components of the framework***

Figure 4.7 shows that all four components in the input phase are important, useful and their description is readable, while for the details in the description of component, a mixed opinions of experts was found. This indicates that for some experts the description of components have sufficient details in it while for other experts, more details needs to be added in the description.

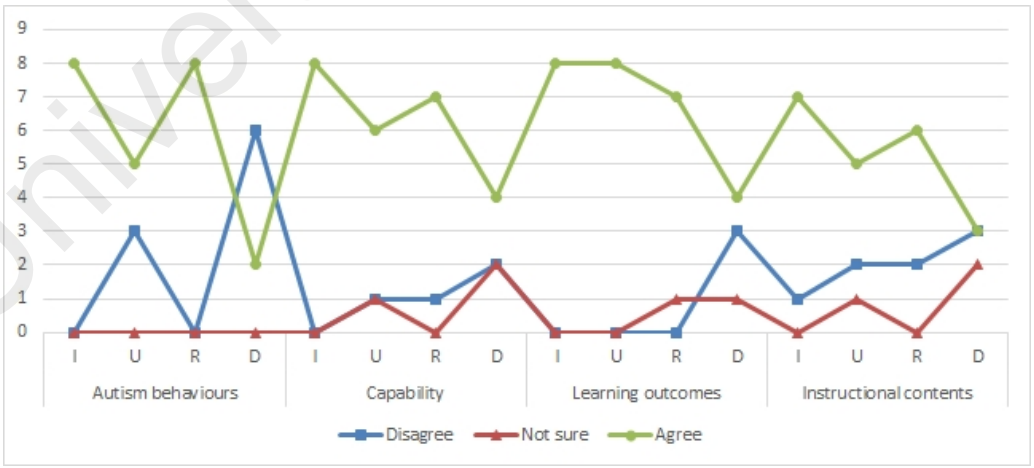

Figure 4.7: Part A – Cumulative frequency of responses for components in the input phase

Figure 4.8 shows that all components in the process phase are important, useful and their description is readable, while for the details in the description of component, a mixed opinions of experts was found.

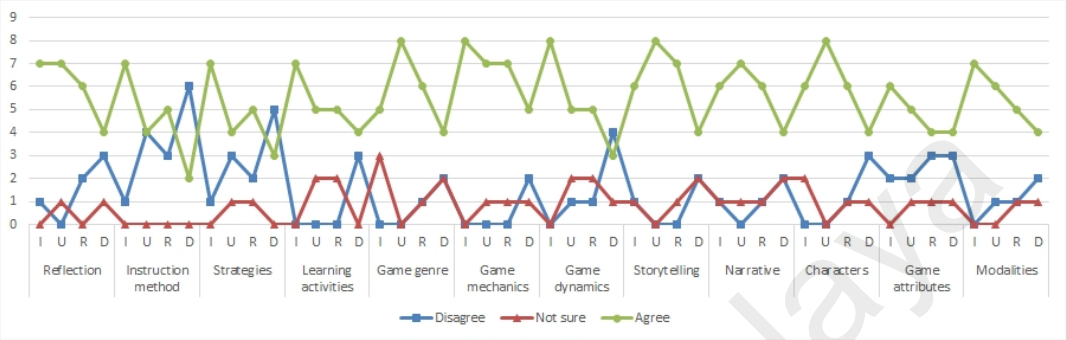

Figure 4.8: Part A – cumulative frequency of responses for components in the process phase

Figure 4.9 shows that all components in output phase are important, useful, readable and have sufficient details.

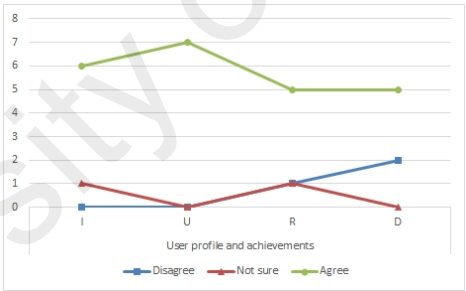

Figure 4.9: Part A – cumulative frequency of responses for components in the output phase

(b) ***Part B – placement of components in phases and IPO structure for framework***

Figure 4.10 shows the cumulative frequency of responses for placement of components in different phases from Q4 to Q6 of Part B. The opinion of experts shows that distribution of all components to input, process and output is logical.

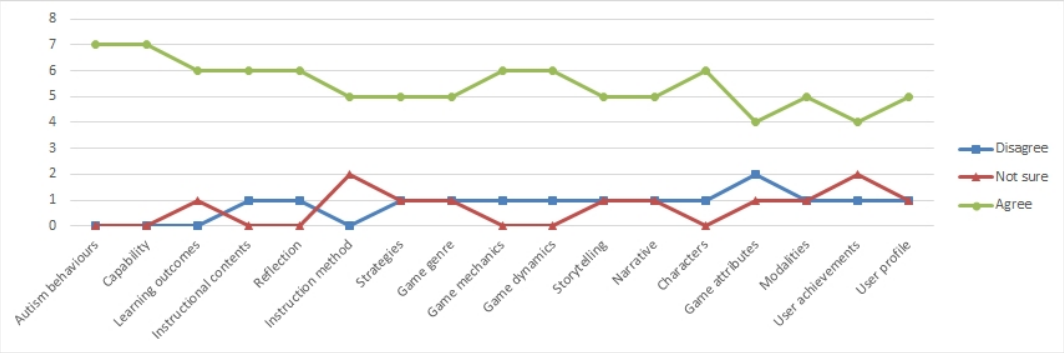

Figure 4.10: Cumulative frequency of responses for placement of components in different phases

Figure 4.11 shows the cumulative frequency of responses for the IPO structure of framework from Q7 and Q9 of Part B4. The expert opinion for Q7 shows that IPO based structure is easy to understand and there is a similarity between structures of IPO and typical games.

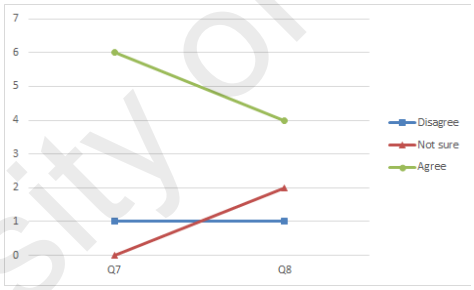

Figure 4.11: Cumulative frequency of responses for the IPO structure of framework

(c) ***Part C – relationships between components***

Figure 4.12 shows the cumulative frequency of responses for relationships between components from Q10 of part C. The expert opinion shows that most of the relationship are correct; the relationships: 1) learning outcomes leads to instruction contents (LO → IC) and 2) game-based learning outcomes are based on the theories (GBLAs → Theories) have received mixed opinion from the experts.

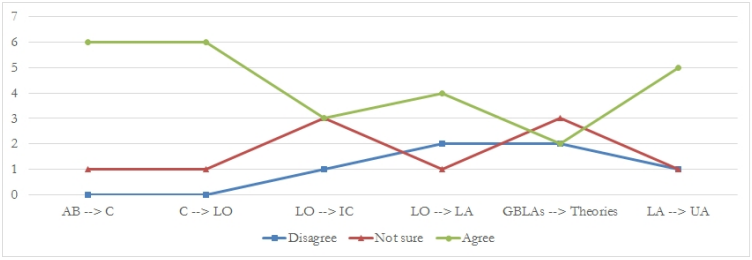

Figure 4.12: Cumulative frequency of responses for relationships between components

(d) ***Descriptive responses provided by the experts***

A total of 94 descriptive responses were collected from the feedback of experts; Table 4.10 shows the distribution of responses into agreement, disagreement, concern and suggestion.

(N=10, 11%) of the overall descriptive responses correspond to agreement; these responses are related to the importance and usefulness of components, relationships between components and the comprehensiveness of framework.

(N=5, 5%) responses indicate the disagreement by the experts regarding information asked in the question. The disagreement is mainly about fewer details in the description component 'characters', placement of components 'user profile and achievements' in output than input and the lack of explanation about the relationships between components.

(N=43, 46%) of the responses are the concerns raised by the experts and half of these concern highlight the fact that some of the components need additional information in the description to make it easy to read, understand and follow. For instance, components like autism behaviours, provide details about the components, but does not indicate which behaviours are supported by the framework and how each behaviour can be used in the design.

Similarly, (N=36, 38%) of the responses are in the form of suggestions provided by the experts; these suggestions are related to add more details, provide some examples and also add references in the components, relationships between components and a sample prototype developed based on the proposed framework.

Table 4.10: Frequency of responses classified into 5 categories associated with 4 parts

	Agreement	Disagreement	Concern	Suggestion	Total
Part A	7	2	19	31	59
Part B	1	2	8	1	12
Part C	1	1	7	2	11
Part D	1	0	9	2	12
Total	10	5	43	36	**94**

Table 4.11 shows the samples of the experts' responses for agreement, disagreement, concern or suggestion.

Table 4.11: Sample responses from the experts

Agreement	Disagreement	Concern	Suggestion
1. Reflection: A very worthwhile component, and (again) reflection can also be promoted by playing e.g. a summary animation of the session that was just finished ... 2. Instruction method: No doubt relevant, and it is good that multimedia instructions are incorporated! 3. Characters: Part of game design, typically hidden from gaming design 4. … the framework is fairly comprehensive, with the comment that no attention is paid to the	1. Character: Not necessarily controlled by AI – the behaviour can be fixed for e.g. NPCs involving with a fixed dialogue structure during the game. 2. User profile is usual input at the beginning and is prior knowledge to the game play… not always 3. For the relations where I disagree it is very difficult to assess if the relation makes sense because the descriptions are insufficient. For example, the relations of the learning activity to user achievements should be	1. 'Autism behaviours' is a very generic term. I assume it refers to Autistic behaviours and symptoms, or behavioural traits or characteristics? And are you referring to a specific spectrum? Could this be made more specific perhaps? 2. Instructional contents: clear, but from the description seems rather limited at this stage. 3. Learning activity: Contextualisation is important for all game play activities 4. The methodology, gaming or	1. Autism behaviours: To be useful in design, the component would need a full listing of the key behaviours, or a listing of behaviour domains and a reference to a more complete listing, and examples of what it means for design practice. 2. Reflection: Give an example to make it clearer. 3. Instruction methods: Again, give some main references for a game developer to follow and learn what are these methods typically? 4. … the theoretical framework is

aesthetics of the game! 5. Coverage seems fine	explained in much more detail.	otherwise, that one devices using the framework should fit the urgency and practice of its participants and its instructors. I guess this is particularly true for children with ASD. I am unsure to what extent behaviours have to be captured.	sufficiently clear, a game prototype is needed to establish the effectivity and coherence of the components …

4.6.6 Changes in the initial version of the proposed framework

The analysis from the quantitative and qualitative responses revealed three types of changes that needs to be incorporated in the framework to produce improved version of the proposed framework. These changes are about: 1) details of the components, 2) new component to be added, and 3) relationships between components.

4.6.6.1 Details of the components:

Following changes have been incorporated in the components:

1. An example of each type of learning outcome has been added in the description of component 'learning outcome'
2. The description of debriefing has been added
3. Examples of instructional contents related to vocabulary have been added in the description of component
4. Autism behaviours: references have been added in the description for further information on the behaviours that can be used for the intervention. The name of component is renamed to 'autistic behaviours and symptoms'.
5. Instruction method: references have been added in the description for further information on the standard methods for ASD that can be used for the intervention.

6. Strategies: references have been added in the description for further information on the strategies that can be used in the serious game for the intervention.
7. The name of component ‘game attribute’ is renamed to ‘game-based learning attributes (GBLAs)’

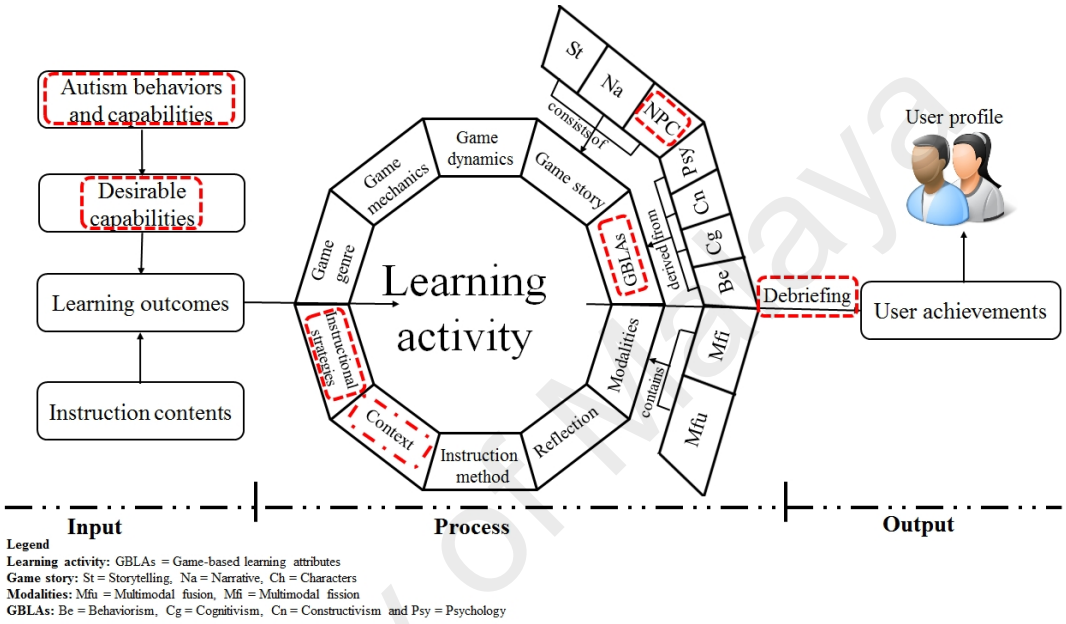

Figure 4.13: modified version of the serious game design framework

4.6.6.2 New component

A new component ‘context’ is added in the learning activity. The description of this component is given below based on the research by (de Freitas & Jarvis, 2006).

Context: The context of any serious game includes information about the three aspects related to the game namely access, technical support, and place. The access is about identification of the location where the game will be used and this would also determine who can access serious game. If it’s to be used in the classroom environment then all the students of class can use game, however, if it’s to be used somewhere outside the classroom then it’s available to the wider range of audience than just

students of that class. The technical support is about determining if the assistance can be provided to the users of the game if they are stuck in the middle of game? Lastly, the place is to determine whether the location whether the game would be used is suitable for the learning? Is it a quiet place for children to concentrate, play and learn or an outside environment where it may be difficult for user to concentrate?

4.6.6.3 Relationships between components

The relationship of components "Game attributes → Theories" was changed to "Game attributes ← Theories" to indicate that game attributes are based on the different theories of learning and psychology theory.

4.7 Expert evaluation 2 with researchers and serious games designers

Expert evaluation 2 is carried out by two different types of experts i.e. researchers working on serious games and game designers. The instruments used, reviews procedures, and data analysis method for quantitative and qualitative are the same as in section 3, hence they are not repeatedly presented in this section. The review of the framework for this study mainly focuses on the components in the input, process and output phases of the framework i.e. the twenty one components as shown in Part A of figure 2. Thus consists of 84 quantitative and 23 qualitative questions

4.7.1 Participants and recruitment

The researchers working in the field of serious games or game designer were invited to part in this study. They were invited by posting information on the Facebook pages, discussion forum and mailing lists related to game design, and seven participants reverted back to be part of the evaluation. They were also asked to provide recommendations of other experts who can be invited to take part in this evaluation. The demographic information of experts involved in the evaluation is shown in Table 4.12.

Table 4.12: Experts' demographic information

Id	Gender	Country	Role	Experience
1	Male	Australia	Game designer	4
2	Male	Pakistan	Game designer	2
3	Male	Malaysia	Game designer	5
4	Male	Malaysia	Game designer	4
5	Male	Canada	Researcher	4
6	Male	Malaysia	Researcher	3
7	Female	United Arab Emirates	Researcher	3

4.7.2 Results

4.7.2.1 Frequency of the opinions provided by the game designer and researchers

This section presents the cumulative frequencies of responses for components in the input, process and output phases of the framework, and they are presented in figures Figure 4.14, Figure 4.15 and Figure 4.16 respectively. The results in the figures show that responses across the 7 experts are consistent and all components in input, process and output phases are important, useful, while details are sufficient and readable. This can be seen through green line or line with circle markers where the value of each marker is at-least 4 which indicates that more than 50% of the respondents selected 'agree'. They are the technical people who are going to be designing the game and according to them, all components are very much needed in the game design.

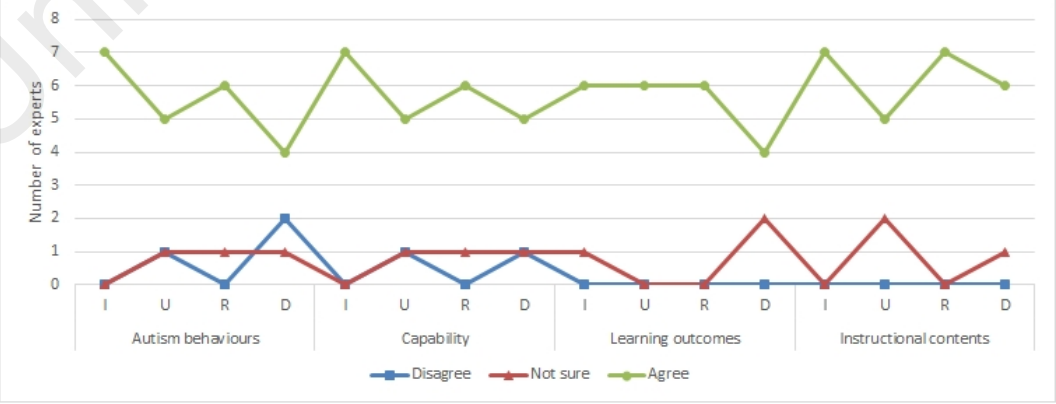

Figure 4.14: Cumulative frequency of responses for components in the input phase

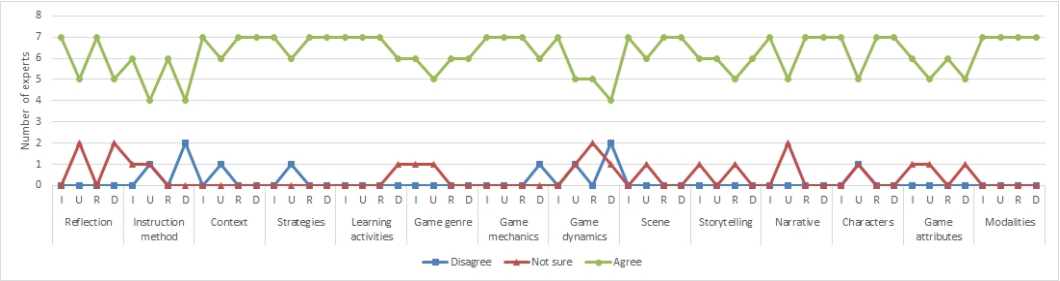

Figure 4.15: Cumulative frequency of responses for components in the process phase

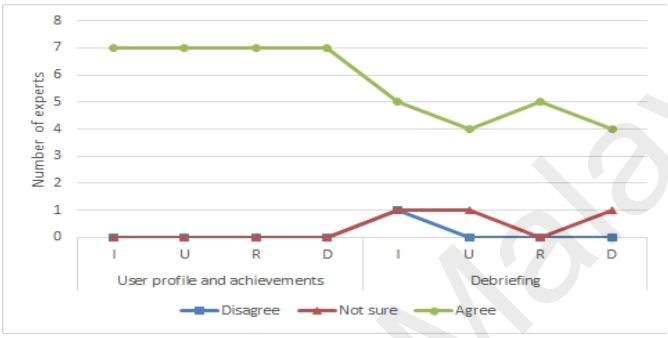

Figure 4.16: Cumulative frequency of responses for components in the output phase

4.7.2.2 Descriptive responses provided by the researchers and game designers

A total of 56 descriptive responses were collected from the feedback of game designers and researchers which include agreement, concern and suggestion while no disagreement was found.

(N=12, 21%) of the overall descriptive responses correspond to agreement; these responses are related to having sufficient details and the way these details are presented in the descriptions of components.

(N=15, 27%) responses indicate the concerns by the experts regarding information asked in the question. These concerns are related to: 1) providing more details on the ASD related components (autism behaviour, instruction methods, strategies) and GBLAs, 3) similarities and differences between some component like GBLAs and strategies, GBLAs and game mechanics, learning outcomes and capabilities, and reflection and debriefing 3) use of game dynamics and 4) purpose of storytelling.

(N=29, 52%) responses indicate the suggestion by the experts regarding information asked in the question. suggestion: examples in components like autism behaviours, learning outcomes, instruction methods among others, using a more descriptive name of components like capabilities, strategies among others, reducing number of components by merging similar components together.

4.7.3 Changes incorporated in the framework

The analysis from the quantitative and qualitative responses revealed that more details of the components needs to be incorporated in the framework. Following is a list of changes that have been added:

1. Autism behaviours: examples have been added in the description to show behaviours related to vocabulary learning that can be used for the intervention.
2. Instruction method: examples have been added in the description to show instruction methods for ASD that can be used for the intervention.
3. GBLAs: examples have been added in the description to show attributes that can be used for the intervention.
4. The name of component ‘capabilities’ is renamed to ‘Desirable capabilities’
5. The name of component ‘strategies’ is renamed to ‘Instructional strategies’
6. The description of components namely GBLAs, strategies, game mechanics, learning outcomes, capabilities, reflection and debriefing have been edited to ensure that they all are difficult.
7. The use of component ‘game dynamics’ has been clarified in the description of component
8. The purpose of ‘storytelling’ has been clarified in the description of component

4.8 Evaluation of serious game design framework – applicability test followed by applicability survey

This section describes the applicability evaluation conducted with the same experts from study two (section 4.7). It begins by providing information on the instruments used and procedures carried out. Finally, the analysis of the results is presented which lead to the revision of proposed framework. The methods used to analyse quantitative as well as qualitative responses are the same as of methods used in study 1 and 2 (section 2 and 3).

4.8.1 Instruments used

The instruments used throughout the evaluation are briefly explained below:

1. **Framework document:** this document contains a revised version of the proposed framework which has been updated after going through 2 expert review studies.
2. **Supplementary information:** this document contains the key findings from the online survey (section 4) conducted with teachers who teach children with ASD.
3. **Game design document:** One of the responsibilities of game designers as a part of their job is to produce a series of documents including game design document, characters design document, levels design document among others to tell others about their game design. In this research, the focus is on a serious game design document as an end result of using proposed framework; the contents and information presented in this design document vary from company to company, project to project or designer to designer, however, it does follow a common thread. The common information presented in such document include:

- An overview description of the game to be developed: 1. title of the game 2. target audience 3. age group 4. platform on which it would work and 5. number of players that can simultaneously play game
- Specifications of the games components used in the design of the serious games.

The same pattern of common information is also used in the template of document that was sent to the experts; the template consists of two parts. Part A gives an overview of the serious games to be designed for children with ASD for learning vocabulary, and Part B divides the specification of the games components divided according to the phases of the framework i.e. input, process and output.

4. **Applicability survey:** The questionnaire consists of ten different categories where each category contains one or more question. The first ten categories are based on the quality model by (ISO/IEC 25010 - Systems and software engineering - Systems and software Quality Requirements and Evaluation (SQuaRE) - System and software quality modelsISO/IEC, 2010) and Purdue usability testing questionnaire (PUTQ) by (Lin, Choong, & Salvendy, 1997). These categories, their associated criteria and the question numbers that fall in the particular category are presented in the Table 4.13.

Table 4.13: Categories, criteria and questions used in the questionnaire

Category	Criteria	Qs#
Understandability	Able to understand the components, and phases	1
Learnability	Able to learn the framework and its components	2
Adaptability	Able to adapt framework and design games for these children to learn vocabulary	3

Usability	Able to use framework and its components to produce design of serious game	4
Memory load	Able to design serious game with less stress and efforts	5
Expectations	Able to meet all the expectation associated with the game design	6
Usefulness	Able to fulfil needs of game design	7
Complexity	Ease with which framework and its components can be used	8
Development	Able to develop game based on the design generated through the framework	9, 10
Willingness / future use	Able to use framework and design games for these children to learn vocabulary in future	11

The list of questions as indicated as 'QS#' in the above table as are as follow:

Q1. Is framework step-by-step understandable following phases and components which are part of it?

Q2. Is framework easy to learn?

Q3. Is framework easy to adapt and design serious game?

Q4. Is framework easy to use?

Q5. Is using framework require minimal memory load to design serious game?

Q6. Did framework meet your expectation to produce design of serious game?

Q7. Is the framework useful to design serious game for these children to learn vocabulary?

Q8. Is the framework less framework?

Q9. Do you think the information presented in your design document can provide insight on game to the members of team?

Q10. Do you think the information presented in your design document can be used to develop game?

Q11. Would you be willing to use framework and design serious game for these children to learn vocabulary?

4.8.2 Study protocol

The experts were sent two instruments: 1) framework document and 2) game design document. They were informed to work on the game design document and send the same once they have provided all the necessary details in the document. Once the document was received, they were sent another email with one attachment of applicability survey instrument and were asked to revert back with the completed survey. An email of appreciation was lastly sent for sparing their valuable time to be part of both studies (study 2 and 3) and providing feedback to improve framework.

4.8.3 Game design documents

Each design document submitted by the expert was individually analysed in terms of specifications of components provided by the experts; this can highlight the most commonly and least commonly used components across the designs. Table 13 provides a summary of specifications for each component provided by the experts in the designs. The components presented in the second column are divided into two types namely ASD components and game components (GCs) as shown in column one. The specifications of all the components are presented from third to eight columns.

Table 4.14: Summary of specifications in game design documents

Type	Components	Design 1	Design 2	Design 3	Design 4	Design 5	Design 6
ASD components	Autism behaviours	Receptive skills, content and grammar is delayed, rigid understanding of words	Difficulty to identify nouns, inappropriate use of verbs	Receptive skill	Receptive and expressive skills	All behaviours	Receptive and expressive skill, difficulty to identify nouns, reverse pronouns, inappropriate use of verbs
	Instruction method	DTT	DTT	DTT	Incidental teaching	DTT	DTT
	Strategies	Explicit, multimedia	Multimedia	Explicit, multimedia	Explicit, multimedia	Explicit, multimedia, capacity, association	Multimedia, association
	Modalities	Basic	Basic	Basic	Basic	Basic	Basic
Game components (GCs)	Desirable capabilities	Cognitive	Cognitive, affective	Affective	Cognitive, psychomotor	Cognitive, psychomotor, affective	Cognitive, affective
	Learning outcomes	✔	✔	✔	✔	✔	✔
	Instruction contents	Animals, birds, fruits, vegetables	Noun, verbs, numbers	Fruits, vegetables, animals, birds, shapes, colours, colours and shapes, people, vehicles, numbers, alphabets	Alphabets, shapes, colours, shapes and colours	Various contents*	Noun, pronouns, verbs, people, vehicle, bathroom items, kitchen items
	Context	Classroom	General	Classroom, general	Classroom, general	General	Classroom, general
	Game genre	Educational	Simulation	Educational	Educational	Multiple	Educational

	Game mechanics	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple
	Game dynamics	Multiple	Multiple	Multiple	Multiple	Multiple	Multiple
	GBLAs (Behaviourism)	FDK, PNP, RWD, RNG	PND, RWD, PFL	RWD, PND, FDK, RNG, PFL, DBF	FDK, RNG, RNG	RWD, IEQ, CNF, LNC, PND	PND, RWD, PFL
	GBLAs (Cognitivism)	MTV	INL, RNG, ATS, MTV	INL, ATS, MTV	MTV. INL, TLS	INL, LNR, ATS, SCF, TLS	INL, RNG, ATS, MTV
	GBLAs (Constructivist)	PRG, ADP	LCN, PRG, HNS	SCF, LCN, PRG, SUR, HNS	LCN, PRG, SCF	LCN, LOC, SUR, ADP, PRG	LCN, PRG, HNS
	GBLAs (Psychology)	ASS, SAL	CHL, FDK, ASS, SAL	SAL, ASS, CHL	ALS, ASS, FDK, CHL	ASS, CHL, ALS, REP, PNP, FAN, MYS	CHL, FDK, ASS, SAL
	Game story		✔		✔	✔	
	Storytelling					✔	
	Narratives				✔		
	Characters		✔	✔	✔	✔	✔
	User profile	Nickname	Name, gender, email address, date of birth	Name, image	Name, image	Name, gender, email address, date of birth, phone#, parents information	Name, gender, date of birth, image
	User achievements	✔	✔	✔	✔	✔	✔
	Debriefing	✔	✔	✔	✔	✔	✔

Note. INL: Incremental learning, LNR: Linearity, ATS: Attention span, SCF: Scaffolding, TLS: Transfer of learned skills, LCN: Learner control , PND: Practice and drill, FDK: Feedback, RWD: Rewards, SAL: Situated and authentic learning, ALS: Accommodating to the learner's styles, ADP: Adaptation, ASS: Assessment, CHL: Challenge, CNF: Conflict, FAN: Fantasy, IEQ: Interaction (equipment), IIN: Interaction (interpersonal), ISC: Interaction (social), LNC: Language/communication, LOC: Location, MYS: Mystery, PNP: Pieces or Players, PRG: Progress, SUR: Surprise, REP: Representation, RNG: Rules/goals, SFT: Safety, SNS: Sensory Stimuli, PFL: Positive feelings, INT: Intensity, MTV: Motivation, HNS: Help and support, DBF: Debriefing

Basic: text, images, audio, video

(a) ***ASD components:***

All the identified behaviours have been targeted in different designs by the experts but receptive and expressive skills are the most commonly used among others. Two instruction methods namely DTT and incidental teaching have been used of which DTT has been in almost all the designs. Different strategies have been used by the experts but multimedia instruction and explicit instruction are the two most commonly used strategies. The experts have used basic modalities in the designs.

(b) ***Game components (GCs):***

The experts have used all three types of cognitive, psychomotor and affective skills across the design documents. The learning outcomes have been defined based on the instructional contents and learning outcomes. The context targeted by the experts include both the classroom and general that include classroom, home or other settings. The game genre used across the designs include educational and simulation among other; the educational was most commonly used. Each game design consists of a number of game mechanics and game dynamics. Each design has used different GBLAs from each of learning theories and theory of psychology. The designers have used different attributes in the user profile; the one commonly used attribute among these designs is the real or nick name of the child. Game story is used in the three designs; each story in these designs consists of one of more of the components and is used to tell a part of the overall story to the user. The storytelling and narratives are each used in one design each; they are the minimally used components across the designs. The characters are used in four designs; among these designs, experts have used animated characters for the interaction and to provide support to the child while they are

playing game. The recording of information related to user achievements is described across the design and debriefing is also used in the games.

Following is a sample of game design document produced by one designer based on the proposed framework.

Part A: Information about game

1. **Title of the game:** Vocab builder
2. **Brief description of game:** This 2D game allow children with ASD to learn various word from different categories through audio-visual medium of instruction. The child is free to select one of the objects to learn and browse through all the images showing different views of an object; this facilitates in the receptive skills. Child can also play different sounds and learn how to pronounce the name of an object and this can improve their expressive skills. Once child has undergone the learning, it can take part in different activities to practice, learn and improve its learning of different objects.
3. **Age group of children:** 6 – 10 years
4. **Number of children who can play game simultaneously:** 1

Part B: Specification of games components

Games components in input:

1. Autism behaviour: one common behaviour i.e. 'struggle to receptively identify objects' among these children is targeted in the design of serious game.

2. Capability: by the end of game, it is expected that child can identify the objects when they listen the names of objects and recall the same objects over the period of time.
3. Intended learning outcomes: the specific learning outcomes to be achieved in these children by the end of this game are: 1) Identify objects and 2) Recall objects over the period of time
4. Instructional contents: the extensive learning of contents to be provided in game include fruits, birds, foods, numbers and alphabets.

Games components in process:

1. Reflection: this informs child about the purpose of undergoing any activity, rectify errors made during activity and provide necessary suggestions to overcome these problems in future.
2. Instruction method: the instruction method to be used in game is discrete trial training (DTT).
3. Strategies: the specific strategies of explicit instruction and multimedia instruction used in the game are described in the following table.

Table 4.15: Specific strategies

Explicit instruction	**Multimedia instruction**
• Students are given definition or other attributes associated with word to be learned • Repeated and multiple exposure of words leads to gain in vocabulary • Pictures, stimulus materials, or instructional examples used in teacher-directed instruction are used in the game. • Pictures, stimulus materials, or instructional examples found in the age-	• Children are taught vocabulary by going beyond text and use other media, for instance, still and animated images, sound and animated characters among others. • Children who cannot read yet will associate printed words with spoken words. Furthermore, autistic children sometimes have difficulty processing spoken words, especially those from TVs, and children who can read may benefit

appropriate general education classroom are used in the game.	from being able to see the words as well as hear them. • Instructions are provided in the form of written words, pictures where needed and the verbal instructions are also simultaneously played to help them in understanding. These instructions are provided in small steps.

4. Game genre: it is an educational game which provides an interactive learning environment for different types of vocabulary items.
5. Game mechanics and dynamics: the game mechanics and the game dynamics associated with this game are mentioned in Table 14.

Table 4.16: Game mechanics and game dynamics

Game mechanics	Game type	Game dynamics
Aim and select	Easy	If correct object is identified: • Name of the object is shown underneath object • Name of the object is played for child to listen and memorize • Increase points by 10 If incorrect object is identified: • Highlight all the correct objects present on the screen for 1 second to provide hint
	Medium	If correct object is identified: • Name of the object is shown underneath object • Name of the object is played for child to listen and memorize • Increase points by 10 If incorrect object is identified: • Highlight one of the correct objects present on the screen random for 1 second to provide hint • Decrease points by 5
	Hard	If correct object is identified: • Increase points by 10 If incorrect object is identified: • No hint is provided like other levels • Decrease points by 5 • Decrease time by 5 seconds

6. Storytelling: the story is centred on a child who face difficulty in the identification of object when the name of object is called.
7. Narrative: no narratives
8. Characters: one helping character is provided in the game for the interaction with child. They can interact with the character to seek guidance when they are not sure what to do next. This character also monitors the activities in game and communicates with child accordingly; for instance, if it does not recognize any activity (action performed through mouse) in 10 seconds then it will auto popup in the middle of screen to ask child if everything alright or they are stuck and looking for a support?
9. Game attributes: a subset of game attributes from that will be used in the game are presented in Table 15 along with their underlying theories.

Table 4.17: Specific game attributes and theories used in game

Behaviourism	**Cognitivism**	**Constructivist**	**Psychology**
1. Reward 2. Practice and drill 3. Feedback 4. Rules/goals 5. Positive feelings	6. Incremental learning 7. Attention span 8. Motivation	9. Scaffolding 10. Learner control 11. Progress 12. Surprise 13. Help and support	14. Situated and authentic learning 15. Assessment 16. Challenge

10. Game story: learning activity is composed of one scene.
11. Modalities: the modalities incorporated in the game include text, images, animated character, animation and sound

Games components in output:

1. User profile and achievements: each user profile include name, gender, email address, date of birth, and all the achievements made in the game.

The serious game prototype developed based on the selected game design document and its details are presented in chapter 7.

4.8.4 Applicability survey

Figure 4.17 presents the cumulative frequency of responses of the applicability survey carried out by the experts after carried out the applicability test of the framework (i.e. after they have experienced the framework and produced design document).

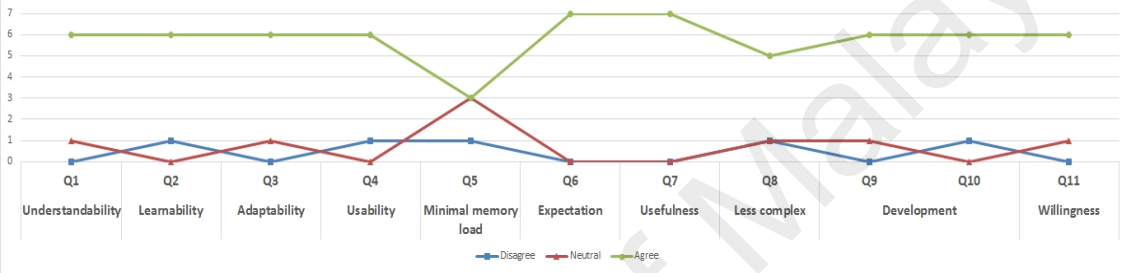

Figure 4.17: Cumulative frequency of responses by the experts

It can be seen that all the experts have mentioned that framework is useful and has met their expectations. According to (N=5 of 7) experts, framework and its components are easy to understand, learn, adapt and use; further, the design documents generated can be used to develop a prototype and they are also willing to use framework in the future as well. The framework is also less complex as mentioned by (N=5 of 7). A mixed opinion of experts was found regarding the use of framework require minimal memory; (N=3 of 7) mentioned that it take minimal workload while the same number of experts were not sure whether it require less or more workload.

4.8.5 Changes incorporated in the framework

Figure 4.18 shows the final version of the frameworks based on the changes incorporated from sections 4.7 and 4.8. The changes incorporated in the figure of final version of the

framework include addition in component ‘context’ highlighted with a red dash dot bounded rectangle and the rename of components highlighted with a red solid dash bounded rectangle.

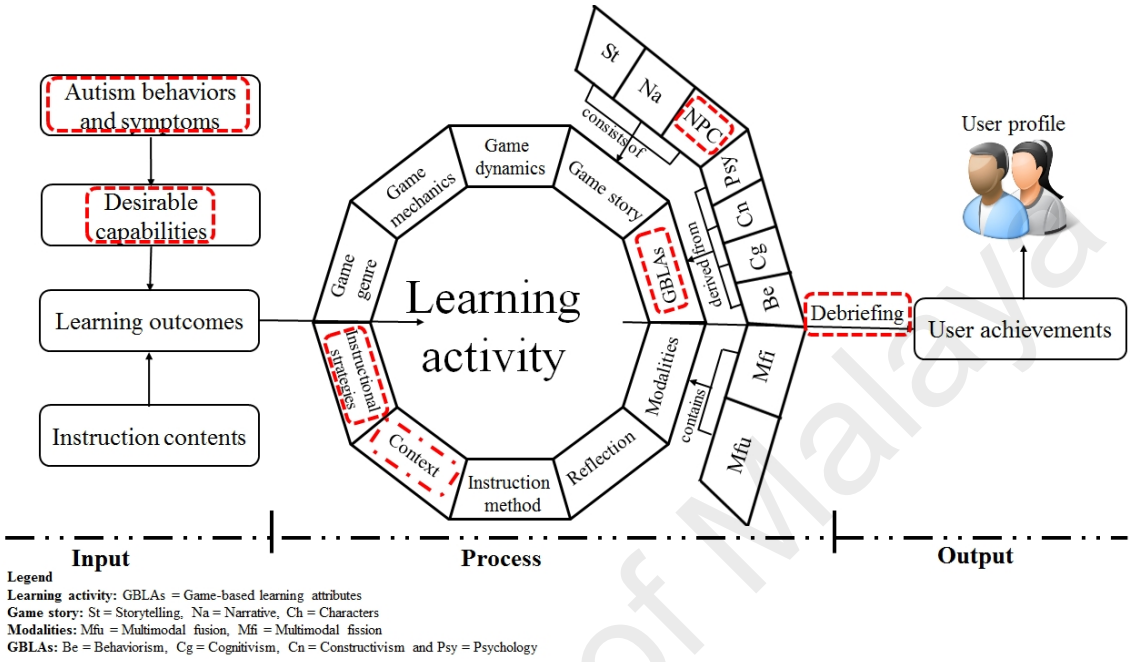

Figure 4.18: Proposed framework to design serious games for children with ASD

4.9 Summary

The serious game design framework proposed in this research was first evaluated through expert reviews by the academicians (who evaluate/use/design such frameworks on a regular basis) focusing on the components used, relations between components and structure of the proposed framework. The revised version of the framework was then further evaluated through expert reviews by the game designers and researchers working in the area of serious games focusing on getting their feedback on the components used in the framework (who work with these components in real-life). Hence, the structure, components and their details of the proposed framework have been effectively refined.

The refined framework was proceeded with the applicability test and six design documents were produced by the experts; each document contained specifications of games components. The analysis of the components used in their design documents showed that:

1. Experts used most of the components and tailored them to fulfil their design needs i.e. serious game for the vocabulary acquisition of children with ASD. Hence, there are a variation in the specifications of games components among the designers. The variations reflect the designer's most valuable assets which are its imagination and creativity. Due to the adequacy of the components provided by the framework, such creativity is supported and not constrained.
2. The specifications of games components in the design documents were structured according to the IPO i.e. input, process, and output, which is feasible and easy to follow.
3. The mapping of components from serious games design to a game prototype provides a practical evidence of the application of the framework.

The applicability survey conducted following their hands-on experience with framework positively reaffirm its practical use. They have expressed their willingness to use framework.

The above shows that components in the framework are adequate and useful to produce designs of games for children with ASD to learn vocabulary.

The description of each component in the Appendix D represents its initial version, while the descriptions presented in section 4.3 represents the final version based on the comments provided by the experts.

CHAPTER 5: SERIOUS GAME PROTOTYPE DEVELOPMENT AND EVALUATION

5.1 Introduction

This chapter completes the third and fourth research objectives of this research. It presents the prototype development of the serious game to demonstrate the logical view of the proposed framework. It is followed by the evaluation of prototype with autistic children and the findings of evaluations are discussed.

5.2 Development of prototype

Chapter 4 presents one game design document for a serious game entitled 'Vocab Builder'. This design document is used as a basis to transform the design into a prototype. The development of the prototype is discussed in this section.

5.2.1 Tools used

This sub-section presents the libraries and tools used for the development of the prototype.

5.2.1.1 Java platform, standard edition (Java SE)[10]

Java SE is used in this research for the development of a prototype that can be compiled, deployed and run on desktops, servers, as well as embedded environments. The vast library of Java provides a wide range of facilities like rich user interface, performance, versatility, portability and security features which are much needed in today's applications.

5.2.1.2 JavaFX Scene Builder

JavaFX which is now part of Java SE allows developers to create desktop applications as well as rich internet applications (RIAs) that can run on a variety of platforms and devices.

[10] http://www.oracle.com/technetwork/java/javase/downloads/index.html

The intention behind the development of this library is to replace Swing components as the standard GUI library in Java SE. The JavaFX Scene Builder is used to create all the screens of the prototype.

5.2.2 Serious game prototype

Figure 5.1 shows different screens of the prototype which have been created based on the design document from chapter 4. Each screen has used one or more components from the framework; the number in each circle correspond to one of the components presented in Table 5.1 while the number in each rounded rectangle represents the screen number. The arrows between screens show that user can move from the current screen represented by the tail of an arrow to the next screen represented by the head of an arrow. The description of each screen is provided in sub-section 5.2.4.

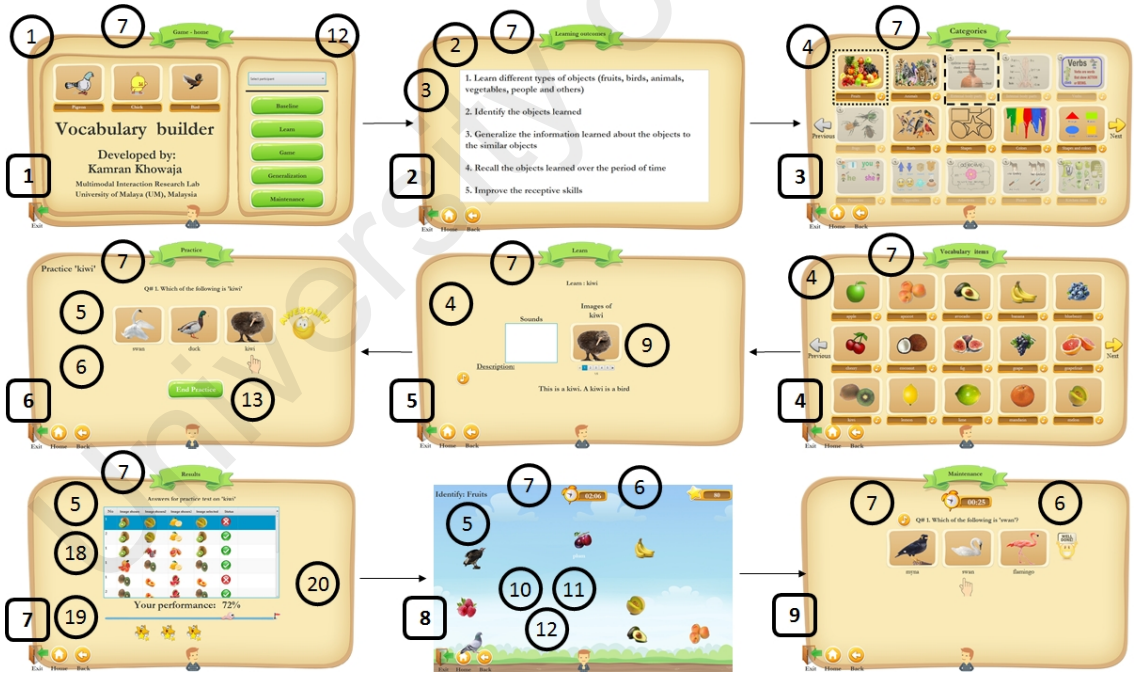

Figure 5.1: Mapping of component from scenario to game

Table 5.1: Components of serious game design framework proposed in this research

S#	Component	S#	Component
1	Autism behaviours	11	Game dynamics
2	Capabilities	12	Game genre
3	Learning outcomes	13	Reflection
4	Instruction contents	14	Game story
5	Learning activities	15	Characters
6	Game attributes	16	Narratives
7	Modalities	17	Storytelling
8	Instruction method	18	Debriefing
9	Strategies	19	User achievements
10	Game mechanics	20	User profile

5.2.3 Game flow

The overall flow of the game across the screens is shown in Figure 5.2; the rectangle represents the screen while the direction of an arrow indicates that the child (the player of the game) can move from one screen to another. For instance, the two-ended arrow between 'Start' and 'Play activity game' screen indicates that the child can move between both of the screens, while, an arrow from 'Activity game' to 'Start' shows that the player can move from 'Activity game' screen to 'Start' but not vice versa.

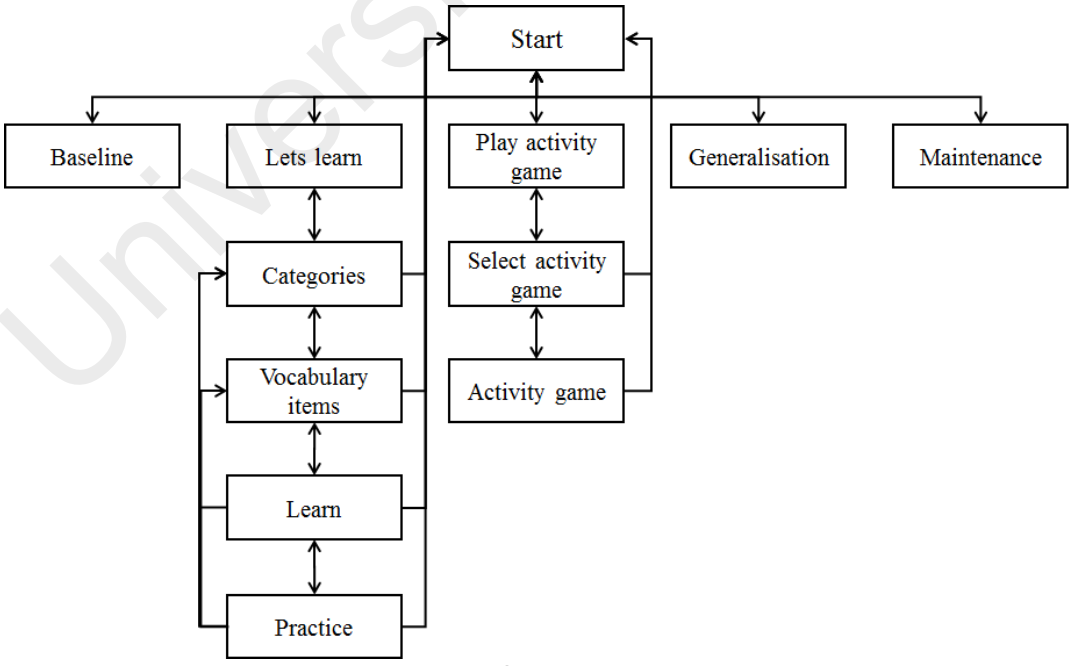

Figure 5.2: Flow of the game between screens

5.2.4 User interface of the game

The sub-section provides brief details of all the screens of the game shown in Figure 5.1.

5.2.4.1 Screen 1 – Main screen:

This screen gives access to five different options (baseline, generalisation, maintenance, learn and game) available in the game that the child can select with the help of a caregiver, teacher or any other person sitting along with him or her. Baseline, generalisation, and maintenance are three different types of tests; the details of these tests are provided in the next section. The learn option allows the child to study different vocabulary items divided into various categories while the game option allows the child to play a game in order to determine the impact of learning different vocabulary items.

5.2.4.2 Screen 2 – Learning outcomes

This screen displays the learning outcomes of playing this serious game to the child; this way the child is aware of the anticipated outcome of using the game.

5.2.4.3 Screen 3 – Categories

This screen shows all the categories of vocabulary items that can be learned through the game. The rectangle with round dots surrounding a category, for instance ‘birds’, shows that there are vocabulary items within this category that the child can learn. However, the rectangle with dashes surrounding a category for instance, ‘internal body parts’, shows that it is currently disabled as there are no items available within this category for him or her to learn. To facilitate the child in the selection of a category, an image of the category is shown as well as the name of the category underneath the image; moving the mouse cursor in the region of any category will read aloud the name of that category to the child. Furthermore, the child can also hear the name of any category by clicking on the music icon beside the

name. If the number of categories available in the game is more than 15 then they are split into multiple screens where each screen contains 15 categories and the child can move between screens by clicking on the previous or next buttons. There are 30 categories altogether which means that these categories are split into two screens. However, at the moment, the child can learn vocabulary items from eleven categories. The prototype currently supports the learning of eleven categories of vocabulary items which include fruits, vegetables, animals, birds, shapes, colours, colours and shapes, people, vehicles, numbers and alphabets.

5.2.4.4 Screen 4 – Vocabulary items

When a child clicks on any of the categories, the next screen is shown to the child which displays all the vocabulary items present in the selected category from which the child can select any item to learn. If the number of vocabulary items in any category is more than 15 then they are split into multiple screens where each screen contains 15 vocabulary items and the child can move between screens by clicking on the previous or next buttons. To facilitate the child in the selection of a vocabulary item, an image of vocabulary is shown as well as the name of the item underneath the image and moving the mouse cursor in the region of any item reads aloud the name of that item for the child. When he or she clicks on any of the vocabulary item, the next screen of learning is shown which is described in the next sub-section. The game currently supports 209 vocabulary items altogether which are divided into eleven available categories as presented in Table 5.2.

Table 5.2: Vocabulary items supported by game

Category	Vocabulary items
Fruits	Apple, grape, apricot, grapefruit, avocado, kiwi, banana, lemon, blueberry, plum, lime, cherry, mandarin, coconut, melon, fig, orange, papaya, pomelo, peach, quince, pear, pineapple, strawberry, pitahaya, watermelon, pomegranate
Vegetables	Carrots, potato, onion, spinach, broccoli, cucumber, eggplant, okra, peas, chickpeas, coriander, mint, kidney beans, corn, ginger, garlic, cabbage, cauliflower, zucchini, sweet potato, chili, bell pepper, bitter gourd, beetroot
Animals	Dog, crocodile, cow, mouse, cat, snake, giraffe, horse, donkey, buffalo, sheep, pig, panda, rabbit, dinosaur, camel, lion, elephant, tiger, zebra, monkey, deer, chimpanzee, goat, rhino, bear, hippopotamus
Birds	Pigeon, swan, chicken, crow, duck, owl, parrot, turkey, flamingo, ostrich, peacock, kiwi, penguin, myna, sparrow, eagle, woodpeckers, kingfishers, vultures, seagull
Shapes	Square, triangle, right triangle, pentagon, circle, rectangle, line, rounded rectangle, parallelogram, trapezoid, diamond, hexagon, heptagon, octagon, decagon, dodecagon, pie
Colours	Blue, pink, green, white, red, black, grey, orange, yellow
Colours and shapes	Blue circle, red circle, blue square, red square, blue triangle, red triangle
People	Doctor, fireman, postman, chef, farmer, police officer, barber, carpenter, plumber, electrician, singer, painter, engineer, dancer, drummer, keyboard artist, pianist, guitarist, nurse, judge, teacher, sweeper
Vehicles	Car, truck, fire truck, bus, school bus, tractor, helicopter, airplane, bicycle, scooter, motorbike, tank, train, ambulance, cable car, crane, ship, forklift truck, submarine, road roller, bulldozer
Numbers	0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Alphabets	A to Z (uppercase and lowercase)

5.2.4.5 Screen 5 – Learn

The learn screen of a vocabulary item displays: 1) all the images associated with an item in a paginated view so that the child can browse through the images one after another by either clicking on the index number of an image or the previous or next buttons. 2) It shows all the available pronunciations of an item in the list box of sounds; each pronunciation can be played by a single click on the name over and over again to improve their receptive skills. These pronunciations are downloaded from the website of Dictionary[11]. 3) It also displays a

[11] http://dictionary.reference.com/

brief description of a selected item that can be read aloud for a child when they click on the music icon. 4) Lastly, the practice button is only shown on the screen when the child has browsed through all the images at least once; this is to ensure that the child has seen all the images of the item and know how the item may look like before he or she attempts a practice test.

5.2.4.6 Screen 6 – Practice

The purpose of practice is to examine if the child has retained an item he or she had just learned. Figure 5.3 shows how the instruction method discrete trial training (DTT) is step-by-step used to facilitate the child in the learning of a vocabulary item. Each circle has a number from one to five; these numbers correspond to the steps of DTT; the purpose of each step is mentioned in chapter 2.

Figure 5.3: Step-by-step use of instruction method DTT to facilitate learning

Following are the details of how five steps of DTT are used in the context of the current game.

1. The child is informed about the practice related to the vocabulary item he or she had just learned. The child is shown a question and asked to identify the correct image of an item; altogether three images are shown from which one is the correct image while the

remaining two images act as distractors i.e. items that also belong to the same vocabulary category as the correct item. For instance, if an image of an apple is shown then the next 2 images shown (acting as distractors) are of different fruits. As mentioned earlier, each item has at least 3 images, therefore, for this practice a random image of all three items is shown to the child. The location of the correct answer is also randomly chosen so that the child does not know where the correct answer could be placed. The names of all the items are also shown underneath respective items.

2. If a child does not answer a question in five seconds of time, a verbal reminder is given to the child by repeating the question again. This is repeated every five seconds until an image is selected by the child.
3. The child selects an image of a possible correct answer and just like the practice button of Step-by-step use of instruction method DTT to facilitate learning appeared; a button of 'End practice' is only made visible on the screen once the child has correctly identified 3 images of an item.
4. A positive feedback in the form of verbal response and image as shown in screen 6 of Figure 5.1; is shown to the child as an encouragement in either case whether the child selects a correct image or an incorrect image. However, if a child selects an incorrect image, a visual hint is given in the form of an index finger pointing to the correct image for one second. For each attempt made to identify a correct image, the information about the attempt number and the time the child took to select an image is recorded for further analysis. The attempt number is initialized to zero each time a new question is shown; the text of all questions remain the same as the question is about the same vocabulary item but the question number is in increment by 1. Similarly, the attempt number is also increased by 1 each time the child selects an incorrect image.
5. A gap of two seconds is given before the next question is shown to the child.

5.2.4.7 Screen 7 – Results

This screen presents the detailed results and the overall achievements. 1) The details about all the attempts made to answer the question and its results are presented in the form of a table; the information displayed include: all three images that were shown to the child for each attempt, the image selected by the child and an icon in the form of a tick or a cross to indicate whether the answer selected was correct or wrong. 2) The percentage of all the questions correctly answered in the first attempt. Lastly, the child is given stars based on the percentage secured; 5 stars are given for percentage of 90 or above, 4 stars for percentage of 80 or above, 3 stars for percentage of 70 or above, 2 stars for percentage of 60 or above and 1 star for percentage of 50 or above, while no star is shown if the percentage is below 50.

5.2.4.8 Screen 8 – Activity game

Once the child has completed the lessons of all the vocabulary items in the selected category, he or she is given an access to play an activity game. The screenshot of the game is shown on screen 8 of Figure 5.1; the purpose of this game is to let the child select all the items that belong to the category they learned. These items are mixed with the distractor items which belong to other categories. The activity games can be individually configured for each child; the information that can be configured in the game include: 1) test items: categories from which items need to be selected by the child, 2) distractor items: categories from which items will act as distractors, 3) total number of items (test items and distractor items) to be shown on screen at any time; 75% of these numbers belong to test items, while the remaining 25% correspond to the distractor items. This number is specified in terms of multiple of four so that distribution of test items and distractor items can be easily done. 4) background image of the game and its opacity, 5) background music of the game, 6)

animated items that can move around the screen, and lastly 7) type of game (easy, medium and hard).

5.2.4.9 Screen 9 – Pre-test and post-test

This screen is used to measure the performance of learning vocabulary before (pre-test) and after (post-test) using prototype. The screen of the baseline is used for pre-test, while the screens of generalisation and maintenance are used for the post-tests. The screen of both pre-test and post-test are similar to that of practice with once difference; these screens also show a clock that displays the time the child has spent on the test. Similar to practice, the text of the question is shown as well as read aloud for the child, and the same positive feedback from the practice screen is given to the child regardless of correct or wrong answer in the tests of baseline, generalisation, and maintenance. However the hint is only given in the baseline and it is provided in the same form as of practice screen.

5.3 Usability study of the serious game prototype

The aim of this usability study is to detect and fix as many usability problems as possible in the serious game prototype before children with autism start using the prototype to learn vocabulary. Such usability problems can distract the user while they are using the prototype; therefore, it is necessary to fix usability problems as early as possible. According to Dix, Finlay, Abowd, and Beale (2004), the evaluation of any system (serious game prototype in this research) can be performed through expert analysis or user participation i.e. potential users of the system.

Dix et al. (2004) have described five different approaches to perform evaluation of the system through expert analysis. These approaches include:

1) Cognitive walkthrough by (Polson, Lewis, Rieman, & Wharton, 1992; Wharton, Rieman, Lewis, & Polson, 1994)

2) Heuristic evaluation by (Nielsen & Molich, 1990)

3) Goals, operators, methods and selection (GOMS) by (Card, Newell, & Moran, 1983)

4) Keystroke-level model by (Card, Moran, & Newell, 1980)

5) Use of previous results as a basis to prove or disprove different aspects of the design

In this research, heuristic evaluation is used as an approach to perform evaluation on the prototype for the following reasons (Dix et al., 2004; Rogers, Sharp, & Preece, 2011; Shneiderman, Plaisant, Cohen, & Jacobs, 2009):

- Relatively inexpensive and fast
- Performed at any phase of product development
- Identifies many usability problems
- Achieves substantially better performance by aggregating the evaluation from several evaluators
- Provides an overview of the complete design
- Pays direct attention to particular aspects of a design and associated problems
- Does not attempt to trace specific user behaviour, rather it critiques the attribute of an interface itself

Nielsen and Molich (1990) have developed a set of ten heuristics that can be used to identify usability problems in the system. This set of heuristics is a generic set and may not identify problems in specialised systems that have been developed; for instance, healthcare system, ambient display, serious games etc. Therefore, the current trend is to develop more specialised heuristics for new technologies and systems. Researchers have typically

developed their own set of heuristics by modifying Nielsen's heuristics together with design guidelines, market research, requirement documents of a specific product, expert reviews, and researchers' own experience in the area of research or a combination of these items (Rogers et al., 2011). There is no specialised set of heuristics to perform usability evaluation on an interactive system for children with ASD. Therefore, a modified set of heuristics was developed as a part based on the extensive review of literature on guidelines to design an interactive system for these children. The work on modified set of heuristics has been published in a journal and the article is appended in Appendix E. Table 5.3 shows the differences between expert analysis and user participation based on the information gathered from Dix and colleagues. The expert analysis was selected to perform usability evaluation based on the factors used to differentiate between expert analysis and user participation, and the need to detect usability problems as early as possible.

Table 5.3: Differences between expert analysis and user participation

Factor	Expert analysis	User participation
Purpose	Detect and fix issues in the design or development which are likely to cause problems to the user when they use system	Conduct experimental use of system
Applicability	All stages of design and development	Later stage of development when working prototype is available
Assessment	Determine whether or not a system upholds accepted usability principles	Assess actual use of the system
Cost	Cheap to perform	Expensive to perform evaluation with the user on a regular basis

5.3.1 Experts and recruitment

The experts selected for this study include academic staff teaching HCI, doing research in the same area and have experience of working with heuristic evaluation. The search for these

experts was performed in Google search engine[12]. Based on the search results, seven experts were identified for this study. The email invitations were sent to these experts and three of them positively replied to the email and confirmed their participation in this study. The demographic information of these experts is shown in Table 5.4.

Table 5.4: Demographic information of experts

Expert#	Gender	Years of experience	Expertise
1	Female	10	Researcher
2	Female	15	Academic staff
3	Male	12	Researcher

5.3.2 Instruments used

Two instruments were used in this study. The first instrument was the serious game prototype developed; the details on the prototype are presented in section 5.2. The second instrument was the modified set of fifteen heuristics developed as a part of this research to evaluate an interactive systems developed for children with ASD. The details on the modified set are appended in Appendix E.

5.3.3 Study protocol

The following steps were carried out as part of the study protocol:

1. Experts were invited through email; they were informed that the evaluation data submitted would remain anonymous, and they were requested to respond to the email concerning their willingness to be part of the evaluation process.
2. Experts carried out evaluation at their own site. A briefing session was held via Skype to inform the experts of a few aspects of the study: i) purpose of evaluation; ii) URL of the

[12] https://www.google.com

serious game prototype to be evaluated; iii) modified set of heuristics to be used; iv) exploration of the prototype; v) evaluation in two phases; vi) identification of usability problems; and vii) submission of data through email. During the evaluation, for each heuristic, experts were asked to write a brief description of all the problems related to that heuristic together with severity ratings between 0 and 4, where 0 corresponded to 'not a problem'; 1, 'cosmetic problem' and 4, 'usability catastrophe'.

5.3.4 Procedure

The usability evaluation of the prototype was conducted in two phases which are briefly described in the following sub-sections.

5.3.4.1 Phase 1

Experts evaluated the serious game for children with ASD and submitted a report of usability problems identified through email. All the reports from the experts were compiled and listed before they were communicated to the developers of the serious game. The developers worked on all the problems and fixed them by making the necessary changes to the serious game.

5.3.4.2 Phase 2

The updated version of the system was uploaded at the same mentioned URL so that the experts could download both copies of the systems for comparison. A copy of report containing the problems found by the experts was emailed to them in the form of questionnaire; for each problem, they were asked to specify if: 1) the identified problems had been fixed, 2) the identified problem had remained unresolved, or 3) they were unsure about it. The experts returned the completed questionnaire through email after they had performed the evaluation.

5.3.5 Results

5.3.5.1 Phase 1

In phase one, a total of 43 problems were identified by the experts. Figure 5.4 shows the number of problems found in this phase, and the average severity of all the problems occurring in the serious game prototype using modified set of heuristics. For each heuristic, the stacked column shows the number of problems found in four severity ratings (cosmetic problem, minor usability problem, major usability problem and usability catastrophe), whereas the line connecting the markers shows the average severity ratings of all the problems found. The cosmetic problems are represented with light downward diagonal pattern, minor usability problems are represented with light upward diagonal pattern, major usability problems are represented with light vertical pattern and usability catastrophes are represented with light horizontal pattern. A single-word name in each column represents the shorter name of heuristics from Table E2 of Appendix E. The frequently violated heuristics include match, consistency, control, and minimalist. Match heuristic was more frequently violated than the other heuristics. The average severity rating of all the problems found is 1.6 which means that most of the problems are either minor or major.

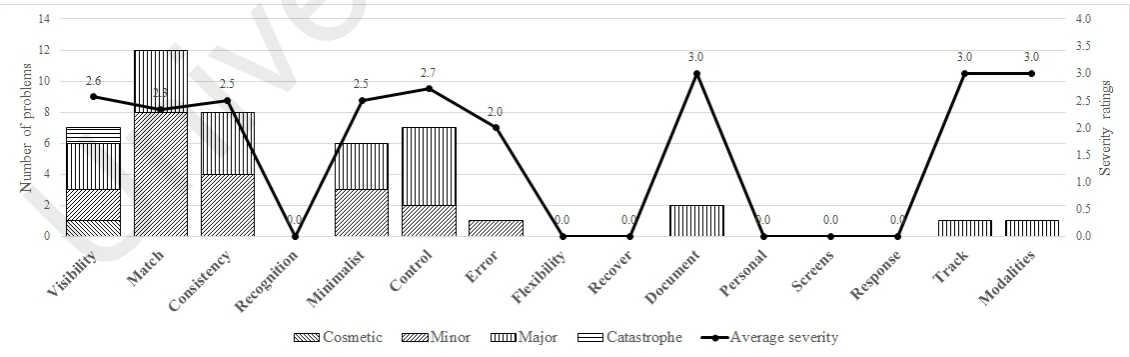

Figure 5.4: Number of usability problems and average severity ratings found in the serious game prototype using modified set of heuristics

From the analysis of the usability problems, it was found that the problems identified for the 'vocabulary items' screen are slightly higher than the problems identified for the other

screens. Therefore, the remaining part of this subsection is focused on the usability problems identified and rectification of these problems in the design of 'vocabulary items' screen. Table 5.5 presents the heuristics by their shorter name, severity rating and usability problems found using modified set of heuristics for 'vocabulary items' screen. The first 5 usability problems in the table are specific to the 'vocabulary items' screen while the remaining three problems are general and need to be resolved across the screens.

Table 5.5: Examples of problems found using modified set of heuristics for the vocabulary items screen

Heuristic	Severity	Problem found
Control	3	There should be a button beside description of sprite which reads aloud the description of sprite when clicked
Consistency	2	The images in the vocabulary items are too small for children to see. The size needs to be consistent with the size of images shown for the category.
Consistency	3	Just like categories screen, place a sound button next to the name of the vocabulary item so that the child can hear the pronunciation of the vocabulary item
Consistency	2	The pronunciation of vocabulary item should also be playable when the child moves the cursor over anywhere in the icon
Match	3	Place a label below the previous and next buttons
Match	3	Exit, home and previous buttons should have labels underneath them
Minimalist	3	The sound on exit, home and previous buttons are lengthy, therefore, if the cursor is quickly moved in between these buttons, multiple sounds are heard simultaneously. Therefore, they should have brief sounds associated with each button
Visibility	3	The sound on exit, home and previous buttons are too long, therefore, if the cursor is quickly moved in between these buttons, multiple sounds are heard simultaneously. Therefore, stop the current sound being played before playing a new sound

Figure 5.5 shows the two screens of 'vocabulary items'; the image on the left-side shows the screen before it was evaluated by the experts, while the image on the right-side shows the same screen once necessary changes (highlighted with dash rounded rectangle) were incorporated into based on the usability problems identified by the experts. The screens of the serious game prototype shown in Figure 5.1 are the updated screens after all the changes were incorporated into based on the usability problems identified by the experts of the study.

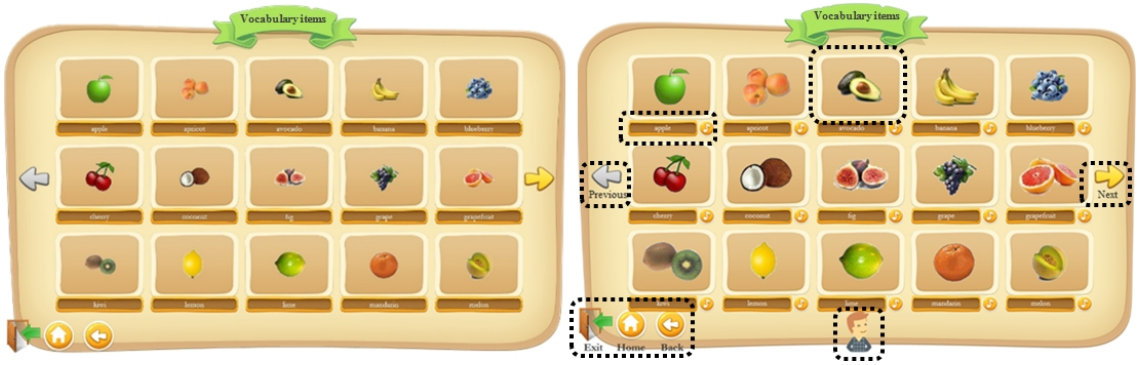

Figure 5.5: Screens of vocabulary items to learn

5.3.5.2 Phase 2

In phase two, each expert was communicated via email to review the updated version of the serious game prototype along with their actual comments in the form of questionnaire. For each comment, they were asked to specify if their identified problems have been fixed, their identified problems have remained unresolved, or they are unsure about it; they were also asked to specify if they find any new issues in the prototype. Based on the completed questionnaires received from the experts, it was found that 40 out of 43 problems were resolved, while the remaining problems remained unresolved and one expert identified two problems in the prototype. The following three unresolved problems and the newly identified problems by the experts were also resolved in the prototype.

1) **Unresolved issue:** When I move the mouse over different buttons the sounds simultaneously play and make it incomprehensible. Therefore, have a smaller sound clip associated with each button.
2) **Unresolved issue:** Categories should be grouped and presented according to the number of items available in each category. Those categories which have one or more vocabulary items to be learned should be presented first followed by those categories which do not have any vocabulary items in them.

3) **Unresolved issue:** On the game screen, when a child selects any object it should show the name of the object for a moment before it disappears. The name should also be pronounced irrespective of whether the child has selected a correct or an incorrect image.
4) **Newly identified problem:** Unable to read the buttons' caption because the Avatar comes in front of the buttons (Game Selector).
5) **Newly identified problem:** The Avatar constantly stays visible at the same location. There should be a way to hide and unhide its appearance or reduce and restore its size.

5.3.6 Discussion

The analysis shows that from the usability problems found through the modified set of heuristics in phase one, most of the problems were fixed in phase two. The unresolved issues and new problems identified were fixed at the end of phase two. The analysis of the frequently violated heuristics from Figure 5.4 shows that Match heuristic was more frequently violated than the other 14 heuristics.

5.4 Experimental evaluation of the prototype

Chapter 4 has presented the serious game design framework proposed in this research to design serious games for these children. It has also shown a number of serious game designs produced by the experts (researchers working in the area of serious games and game designers) and one of the game design was presented in detail. This design was transformed into a serious game prototype and presented in section 5.2 of this chapter. The aim of this experimental evaluation is to examine the effectiveness of the serious game prototype entitled 'vocab builder' (section 5.2) in improving the performance of learning vocabulary among children with autism.

5.4.1 Review of design for experimental evaluation

The review of literature on children with ASD (studies in SLRs discussed in section 2.5 and appendix A) has shown that single-subject research design (SSRD) and group-based designs are commonly used to investigate the effectiveness of intervention among these children. Both of these designs are also commonly used designs across different fields including education, psychology, and health among others (Creswell, 2012). Table 5.6 shows the comparison between both designs. The comparison is based on a number of factors which are shown in the first column. These factors and the details have been compiled from various sources (Cardon & Azuma, 2011; Miller, 2003; Wolery & Harris, 1982; Zhan & Ottenbacher, 2001) instead of being taken from just a single school of thought. The national research council has highlighted that researchers working with children with ASD have frequently used the SSRD to provide intervention of some skill (National Research National Autism Center NAC, 2001). The SSRD is chosen for this study to analyse the performance of learning vocabulary among these children through the serious game based on various factors including applicability, measurement, data analysis, and statistics among others. The remaining part of this sub-section highlights the importance and details of SSRD.

Table 5.6: Differences between single-subject research design (SSRD) and group-based design

Factor	SSRD	Group-based design
Applicability	Most commonly used	Least commonly used
Number of subjects	Minimum: 1, recommended: 3 and maximum: 10	1 or more
Subject	Each subject acts as its own control	Subjects are divided into groups
Extraneous variable	Controls	May control
Design flexibility	Design can be changed	Design change is not possible
Generalisability of findings	Limited	Similar to groups
Measurement	Repeated number of times	Few

Independent variable	Systemic replication during baseline and intervention	Single time
Cost	Low	Can be high
Data analysis	Visual analysis	Statistically
Statistics	No or limited use of statistics	Significant use of statistics
Condition to use statistics	Instability in the data	No condition

The purpose of using SSRD design is to learn about the change in the specific behaviour of an individual over a period of time. This is where this design is different from the group-based design; in SSRD, the change in a specific behaviour is measured throughout the duration of the study, whereas, in the group-based design, the behaviours are only measured before the start and at the end of an intervention. SSRD is used to show or establish a causal relationship between the intervention used in the research and the result of an individual (Neuman & McCormick, 1995). There are five different designs of SSRD which are briefly described below (Byiers, Reichle, & Symons, 2012):

1) Pre-experimental (or AB or A/B) design: this design is the simplest design of SSRD; it consists of two phases: A (baseline) and B (intervention). Several baseline sessions are conducted to establish the pre-intervention performance. This shows A's continuous assessment is carried out during the intervention. The performance between baseline and intervention are compared to investigate the effectiveness of the intervention. A possible example of this design would be the use of CBI to investigate its effectiveness in learning mathematics among children with autism.
2) Reversal or withdrawal (or ABA or A/B/A, ABAB or A/B/A/B) design: this design is a variation of the earlier design where the first A and B are the same. The ABA reversal is the first variation in which the researcher first investigates the performance during A, provides an intervention during B, and then withdraws the intervention to investigate if the performance goes back to the performance measured in A. Another variation of this

design is the ABA withdrawal design in which researchers can implement one or more B (interventions) where each B has an A before and after.

3) Multiple-baseline/multiple-probe design: Multiple-baseline is a frequently used design; in this design, each participant is systematically introduced to the intervention at a different time to avoid diffusion of intervention among the participants. In this design, one of the variables, which include participant, behaviour, stimuli or setting, can be examined while the other variables are kept constant. A possible example of this design would be to investigate the effectiveness of reading fluency program among children with autism. There are cases where simultaneous and continuous data collection across the leg (panel in which data is plotted) is either not feasible or not necessary. This can be achieved with a variation of multiple-baseline design called multiple-probe design; this design combines multiple-baseline and probe procedures together. In this design, an intermittent probe replaces the continuous assessment in the baseline to measure performance of each phase during baseline. This reduces the burden of data collection because the probe removes the need for continuous data collection in all the phases simultaneously.
4) Alternating interventions and adapted alternating interventions designs: this is another type of design in which two or more interventions are relatively examined to investigate which one among them is more effective and produces better outcome. An example of this design is the comparison of three different methods of teaching skills to children with autism: 1) traditional method of teaching, 2) use of CBI, and 3) use of traditional method and CBI together.
5) Multiple-interventions design: there are various situations in which the researcher not only wants to investigate the effectiveness of intervention but they are also interested to investigate the effectiveness of intervention in comparison to another alternate intervention. One simple possibility is to extend the simple withdrawal design and extend

it with one of more intervention or phases. The simplest design of this type can be ABACAC where the A and B represent the baseline and actual intervention while C represents the alternate intervention. Furthermore, the second B not only acts as a withdrawal of actual intervention but it also acts as a baseline for alternate intervention.

Table 5.7 presents four studies on language comprehension skills of children with ASD which are based on SSRD. These studies have been extracted from Table 2.4 of section 2.5.3 in chapter 2. For each study, the details presented include: 1) skills targeted, 2) material used, 3) design used, 4) data collected, 5) duration of the study, 6) data collection instances, and 7) type of analysis performed. This would support in the identification of appropriate details that can be used in the experimental evaluation of prototype with these children. The remaining part of this subsection presents the analysis from each column of Table 5.7.

Skills targeted: two studies have targeted receptive identification of pictures and vocabulary, one study has targeted matching words with the orthographic symbols and one study targeted identification of words using the Nonverbal Reading Approach (NRA).

Participants: The number of participants in each study is between 3 and 6. The average number of participants across the studies is 5.

Materials: O. E. Hetzroni and Shalem (2005) identified 8 words for participants with the help of teachers and parents. Bosseler and Massaro (2003) and Massaro and Bosseler (2006) identified 18 and 24 vocabulary items which were equally distributed into 3 and 4 groups respectively. These items were selected from 18 categories. Coleman-Martin et al. (2005) have not specified the material used in their study.

Table 5.7: Studies on language comprehension skills of children with ASD

Source	Skills targeted	Materials	Design	Data collected	Duration of the study	Data collection instances	Analysis
Massaro and Bosseler (2006)	Receptive identification of pictures and vocabulary	24 (12% of at-least 196 items) vocabulary items divided into 4 equal groups	Within-subject design followed alternating treatment	Number of correct receptive responses	30 minute sessions, on 3 days per week until all 24 vocabulary items are correctly identified in the post-tests across two consecutive training sessions	Pre-training and post-training	Visual
Bosseler and Massaro (2003)	Receptive identification of pictures and vocabulary	18 (9% of at-least 196 items) vocabulary items uniquely selected for each participant and divided into 3 equal groups	Within-subject design followed single-subject multiple-baseline design	Number of correct responses	33 days	Pre-training, training, post-training and generalisation	Visual
O. E. Hetzroni and Shalem (2005)	Matching word to sample	8 food items were selected for each participant. Same items are used for all participants	Multiple-probe design across participants	Number of correct responses	Not specified	Baseline, intervention, generalisation and maintenance	Visual
Coleman-Martin et al. (2005)	Promote word identification using the Nonverbal Reading Approach (NRA)	Not specified	Multiple-treatment design with drop-down baselines	Number of vocabulary words identified correctly	Not specified	Baseline, intervention across three conditions (Teacher only, teacher + CAI and CAI only)	Visual

Design: The authors of the studies mentioned in the table have mainly used three out of six designs of single-subject research design (SSRD) which include alternating treatments, multiple-baseline/multiple-probe design and multiple-treatment design.

Data collected: It can be seen that across the studies, data collected is in terms of number of correct responses given by the autistic children against the questions asked.

Duration of the study: Bosseler and Massaro (2003) have specified the entire duration as 33 days, while Massaro and Bosseler (2006) have only specified the duration of each session which was conducted thrice a week. They have further mentioned that these sessions were performed until the child correctly identified all 24 vocabulary items in two consecutive post-tests. The two studies (Coleman-Martin et al., 2005; O. E. Hetzroni & Shalem, 2005) have not specified duration of the study.

Data collection instances: The data collection instances shows that data has been collected before (baseline or pre-training), during (intervention or training) and after (generalisation, maintenance or post-training) intervention.

Analysis: The results from the SSRD can be interpreted using various methods of statistical analysis (Dugard & File, 2001) as cited in (Horner et al., 2005). However, the visual analysis is the traditional method to analyse data gathered during each phase of the design (Horner). It can be seen that the authors of all the studies have used visual analysis than statistical analysis to examine the effectiveness of the intervention based on the data collected across the studies.

Outcome: The results of all studies have shown that learning among participants improved from the baseline to the intervention and generalisation and maintenance.

Section 5.4 introduced the general aim of this experimental evaluation. A refined version of the aim is presented here based on the studies presented in Table 5.7. The aim of this experimental evaluation is to examine the effectiveness of the serious game prototype entitled 'vocab builder' (section 5.2) using ABA design of SSRD in improving the receptive identification of vocabulary items among children with autism before (during baseline) and after using the prototype (during intervention and maintenance following withdrawal of intervention). The improvement in receptive identification of vocabulary items is measured in terms of the number of correct responses given and the number of attempts made to identify the correct responses.

5.4.2 Method

The Table 5.7 shows that each study has used a different design of SSRD; in this research the ABA (basic withdrawal) design of SSRD is used. The purpose of using this design is to examine the effectiveness of using serious game prototype to improve autistic children's learning of vocabulary by observing their behaviour over a period of time i.e. before (during baseline phase), during the intervention and a maintenance tests at the end of week one and week two following the withdrawal of intervention.

5.4.3 Participants

For this research, a total of five children with autism were recruited to be a part of this evaluation. This number is marginally higher than the number of participants recommended for SSRD as presented in Table 5.6. However, this number is the same as the average number of participants used in the studies related to language comprehension of children with ASD (Table 5.7). Following criteria were used to recruit participants for this study:

1. Child is diagnosed with autism (mild to severe)

2. Child has difficulty in learning different categories of vocabulary; for instance, fruits, vegetables, numbers, alphabets etc.
3. Child has a basic working knowledge of computers
4. Child is within an age group of 6 to 10 years old

The participants were recruited from CADS Enhancement Centre which is located in Kuala Lumpur, Malaysia and provides intervention of different skills to children with ASD. The parental consent was sought before participants were involved in this experimental work. Brief information about each participant is presented in the Table 5.8.

Table 5.8: Information about the participants

Participant#	Gender	Age	Diagnosis
Participant 1	Male	9	Mild autism & ADHD
Participant 2	Male	8	Mild autism
Participant 3	Male	10	Mild autism
Participant 4	Male	6	Mild autism
Participant 5	Male	7	Mild autism & ADHD

5.4.4 Study protocol

The principal of the centre was invited to allow their children to take part in this study. The principal nominated one female teacher working with these children as a focal person to provide all the support needed throughout this experimental evaluation. The teacher was informed that: 1) The identity of children participating in the study would remain anonymous; they would be referred to as “Participant 1”, “Participant 2” and so on. 2) Pictures of participant’s interaction with the serious game will be taken but no face of any participant would be revealed in any of the reports written based on this study.

The focal person was asked to identify 5 children who face difficulty in learning one or more categories of vocabulary mentioned in section 5.2.4.3.

From the Table 5.7, it can be seen that Massaro and Bosseler (2006) continued evaluation until participants met the criteria set by the authors. Bosseler and Massaro (2003) is the only study which have mentioned the duration of the research i.e. 33 days; the researchers used this duration to provide intervention of 18 vocabulary items from 28 categories. In this study, however, a total of 24 working days were reserved for the evaluation based on the availability of participants. This duration is solely used for the intervention of the vocabulary item bird. A slot of two hours (20 minutes per participant in which they were given a two minutes break towards the end of 10 minutes) per day across five weeks were reserved for the evaluation. Table 5.9 provides a summary of all the tasks that were performed during the five-week sessions. The number of days for intervention is kept considering the number of items to be learned by each participant. It would take an average of ten days if 2 items (10 minutes per item) are learned each day. The focal person highlighted that some participants may need a recap on some of the vocabulary items and some participants may not be present on any day, therefore, additional days were added for the intervention.

Table 5.9: Summary of the tasks performed during the three week sessions

Week	Days	Session	Participants	Tasks
0	2	Pre-session	All	Introduction to serious game 'vocab builder' and how to use it
1	3	Baseline	All	Initial assessment (section 5.4.7.1)
1 to 4	15	Intervention	All	Learn vocabulary (section 5.4.7.2)
5	2	Maintenance 1	All	Test at the end of week one after intervention was over (section 5.4.7.3)
5	2	Maintenance 2	All	Test at the end of week two after intervention was over (section 5.4.7.3)

5.4.5 Instruments used

The serious game was developed (section 5.2) and ran on an HP Envy 17 Notebook PC which has Intel(R) Core(TM) i7-4702MQ CPU @ 2.20GHz with 8 GB memory and, NVIDIA GeForce GT 750M and Intel(R) HD Graphics 4600 graphics running Microsoft Windows 8.1 64-bit operating system. The environment setup for the intervention is shown in Figure 5.6. It shows that the researcher is sitting next to the participant for assistance if needed and when the participant is not sure what to do.

Figure 5.6: Setup of environment for the intervention

5.4.6 Material used

The prototype provides support in learning eleven different categories of vocabulary items as presented in Table 5.2. The focal person was asked to identify the categories in which recruited participants face difficulties so that intervention of specific vocabulary items can be provided through the prototype. The person identified birds, fruits, people, and colours and shapes as more crucial than others. Therefore, in this study, all 20 vocabulary items in the category of birds were selected with the consent of focal person; these items represent the 9.56% of all the items supported by the prototype. From Table 5.7, Bosseler and Massaro (2003) have used 18 (out of 169 i.e. 9%) of all the items which is almost the same number of items used in this study. Similarly, Massaro and

Bosseler (2006) have used 24 (out of 169 i.e. 12%) of all the items which is marginally higher than the items used in this study. Both studies have used items from a collection of 28 categories; this shows that there is less than 1% chance to select an item from each of the 28 categories. This makes it difficult to make an overall understanding of participant's knowledge in terms of each category. Therefore, in this study, seven different vocabulary items were chosen from the birds for this study to gather performance during baseline and the maintenance; these items were identified with the help of the focal person. The purpose of using seven (out of twenty i.e. 30% of birds) was to get an understanding of participants' knowledge in distinguishing birds before and after using prototype. All twenty vocabulary items were used in the intervention in comparison to the number of items used during baseline and maintenance.

5.4.7 Procedure

A training session was conducted with the participants before beginning the formal investigation of the serious game. The participants were trained to sit in a chair, use a computer, listen to verbal instructions given by the computer and respond on screen by using the mouse.

The procedure used to collect data at three different stages i.e. baseline, intervention, and maintenance is described below:

5.4.7.1 Baseline

An initial assessment in the form of six baseline probe sessions were conducted prior to participants started using the serious game to learn vocabulary. This assessment was conducted to measure the current level of knowledge in the identified categories of vocabularies. Three sessions were conducted on the first day with a break of 2 minutes in between each session while the remaining three sessions were conducted on the

second day. For each item, a question is asked to identify the correct image of an item by showing three images including the item itself and two distractors from the same category as the item. The sequence in which seven vocabulary items need to be identified by the child, along with the position of the correct item and two distractors are all randomized by the game so that the child cannot predict the question sequence of the item and the position of the correct item. This technique is also followed in the intervention, and maintenance.

5.4.7.2 Intervention

During the intervention, each participant went through all the vocabulary items present in the identified category. Two sessions of ten minutes each was conducted with every child and a break of 2 minutes between sessions was given to the participants to relax. During each day, if a child was found not focused in the first session then the second session was not conducted on that day. Each session correspond to the learning of one vocabulary item from the identified category. For each vocabulary item, once the participants saw and memorized all the images associated with the item, they attempted a practice test where they were asked to identify the current image of the item they had just learned. As highlighted in section 5.2.4, the participant needs to identify at-least three correct vocabulary items before they can go back to either learn the same item again or choose to learn another item.

Once learning of all the birds was completed by an individual child, he or she was given an access to play an activity game for two days. Each day, the child played an activity game once for the duration of 3 minutes; this duration was set after consultation with the focal person keeping in mind these children easily get distracted and bored. The activity game was specifically configured for these children as follow:

1) Test items: birds
2) Distractor items: animals and fruits
3) Total number of items (test items and distractor items): 4 (3 test items and 1 distractor)
4) Background image of the game and its opacity: clouds with opacity of 0.8
5) Animated items that can move around the screen: snail and snake
6) Type of game (easy, medium and hard): easy

5.4.7.3 Maintenance

Three probe sessions of maintenance were conducted at the end of week one and week two following the withdrawal of intervention to measure the retention of vocabulary items learned during the intervention. During each week, two sessions were conducted on the first day, while the last session was conducted on the second day. If two sessions were conducted on the same day then a break of two minutes was given in between each test. The same set of items from baseline were used in the maintenance, however, the images used for these items were those used in baseline or intervention.

5.4.8 Data measurement and analysis

This subsection describes the measurements performed during this evaluation. The approach used to measure the correct responses and the attempts made to identity correct responses during each session are the same in all three phases (baseline, intervention and maintenance).

5.4.8.1 Measure the frequency of correct responses

Following variables are used during each session:

1) Number of correct response: the value of this variable is reset to 0 at the start of the session.
2) Total number of responses: the value of this variable is reset to 0 at the start of the session.
3) Response: For each question, if the child selected a correct response for the question, then the value of 1 is assigned to the variable and the value of variable number of correct responses is incremented by 1, otherwise, the value of 0 is assigned to the variable. The value of variable total number of responses is also incremented by 1.

Following formula used to calculate the percentage of correct responses at the end of each session:

$$Percentage\ of\ correct\ responses = \frac{(number\ of\ correct\ responses * 100)}{total\ number\ of\ responses}$$

5.4.8.2 Measure the frequency of attempts made to identify the correct response

The variables used to calculate the number of attempts are:

1) Number of attempts: this variable is initialised to 1 when a new question is shown to the child.
2) Sum of attempts: this variable is initialised to 0 at the start of the session.
3) Total number of questions: this variable is initialised to 0 at the start of the session.
4) Attempt: the value of this variable is initialised to 0 when a new question is shown to the child. If the child selected an incorrect response for the question then the value of number of attempts variable is incremented by 1. If the child selected a correct response for the question then the value of number of attempts variable is

added to the sum of attempts variable and the value of total number of questions is incremented by 1.

Following formula is used to calculate the value of number of attempts at the end of each session.

$$number\ of\ attempts = \frac{sum\ of\ attempts}{total\ number\ of\ questions}$$

5.4.8.3 Examine the effectiveness of serious game prototype

The visual analysis was also used to examine the effectiveness of the prototype based on the two parameters: 1) number of correct responses and 2) number of attempts. In the visual analysis, each graph of the participant is examined one after another to assess the change that occurs in the behaviour from the baseline to the intervention and maintenance.

5.4.9 Results

The percentage of correct responses and the number of attempts made to identify the correct items during each session of all the participants are shown in figures Figure 5.7 – Figure 5.11 in sections 5.4.9.1 – 5.4.9.5. The upper part of each figure shows the percentage of correct responses while the lower part shows the number of attempts made to identify the correct responses. Each figure is divided into four parts through vertical dash lines: the first part contains performance during baseline. The performance of intervention is shown in the second phase while the performance in the maintenance i.e. at the end of week 1 and 2 following withdrawal of intervention are shown in the third and fourth parts respectively.

5.4.9.1 Performance of participant 1

Figure 5.7 displays the percentage of correct responses and the number of attempts made to identify the correct items by Participant 1. Following subsections present the results in terms of: a) number of correct responses, and b) number of attempts made to identify the correct responses.

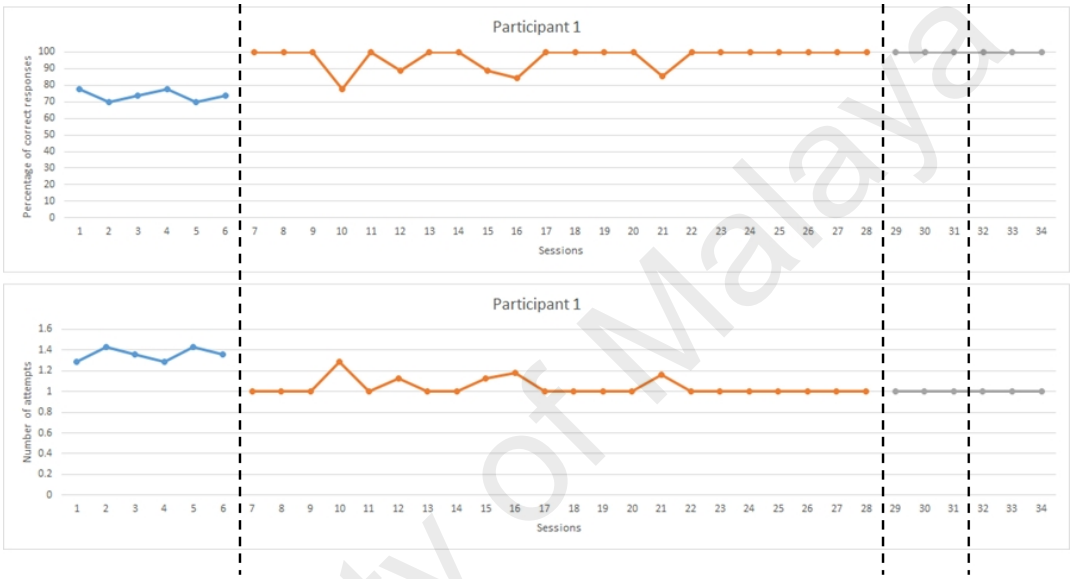

Figure 5.7: Performance of participant 1

*(a) **Correct responses***

The mean performance of the participant during baseline was 72%. The use of serious game during intervention to learn different bird improved the performance of participant 1 to 97%. The participant had 100% retention during maintenance at the end of week 1 and 2 following withdrawal of intervention.

The results of post-intervention activity game played on the first and second day shows that participant 1 correctly identified (55 out of 55 i.e. 100%) and (43 out of 44 i.e. 97.72%) birds in each of the three-minute activity games.

*(b) **Number of attempts***

The mean number of attempts made to identify the correct bird during baseline was almost one and half i.e. 1.4 which becomes lower and improved to 1 after learning through serious games and it remained the same during maintenance at the end of week 1 and 2.

5.4.9.2 Performance of participant 2

Figure 5.8 displays the percentage of correct responses and the number of attempts made to identify the correct items by Participant 2. Following subsections present the results in terms of: a) number of correct responses, and b) number of attempts made to identify the correct responses.

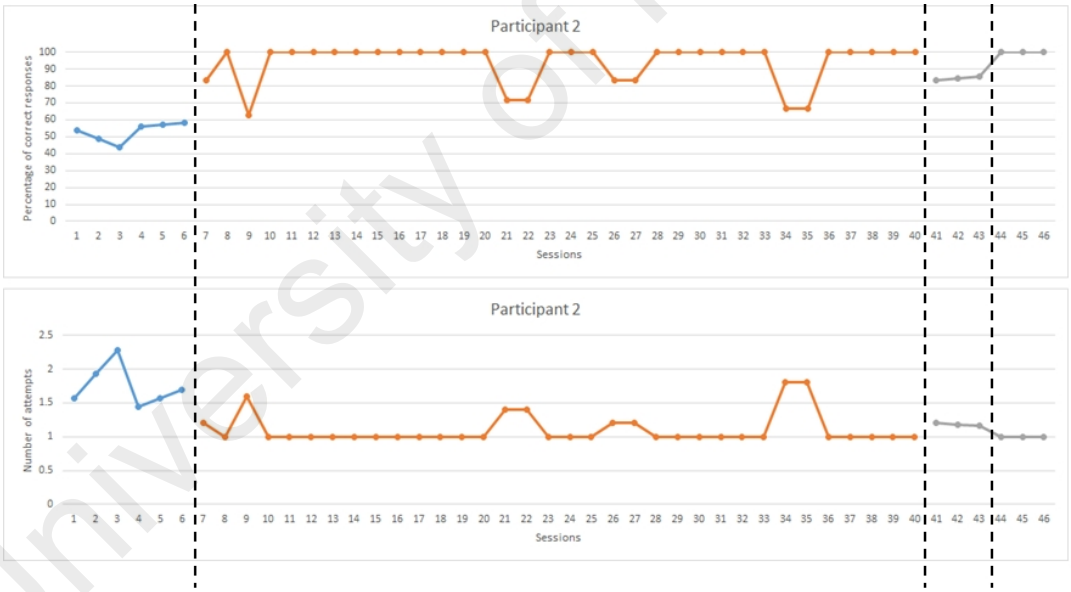

Figure 5.8: Performance of participant 2

*(a) **Correct responses***

The mean performance of the participant during baseline was 53%. The use of serious game during intervention brought a lot of improvement in the performance of participant 2 and the performance increased to 94%. The participant had 92% retention during maintenance at the end of week 1 and 2 following withdrawal of intervention.

The results of post-intervention activity game played on the first and second day show that participant 2 correctly identified (50 out of 53 i.e. 94.34%) and (69 out of 70 i.e. 98.57%) birds in each of the three-minute activity games.

*(b) **Number of Attempts***

The mean number of attempts made to identify the correct bird during baseline was 1.8 which becomes lower and improved to 1.1 after learning through serious games and it remained the same at 1.1 during maintenance at the end of week 1 and 2.

5.4.9.3 Performance of participant 3

Figure 5.9 displays the percentage of correct responses and the number of attempts made to identify the correct items by Participant 3. Following subsections present the results in terms of: a) number of correct responses, and b) number of attempts made to identify the correct responses.

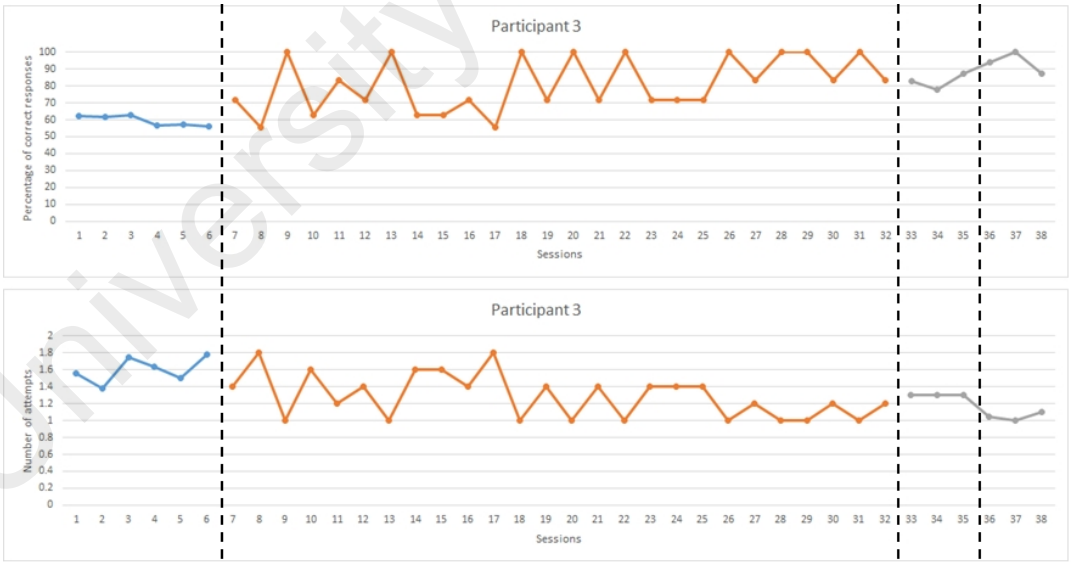

Figure 5.9: Performance of participant 3

*(a) **Correct responses***

The mean performance of the participant during baseline was 59%. The use of serious game during intervention brought an improvement in the performance of

participant 3 and the performance increased to 81%. The participant had 88% retention during maintenance at the end of week 1 and 2 following withdrawal of intervention.

The results of post-intervention activity game played on the first and second day show that participant 3 correctly identified (19 out of 21 i.e. 90.48%) and (24 out of 26 i.e. 92.31%) birds in each of the three-minute activity games.

(b) ***Number of Attempts***

The mean number of attempts made to identify the correct bird during baseline was 1.6 which becomes lower and improved to 1.3 after learning through serious games and it remained almost the same i.e. 1.2 during maintenance at the end of week 1 and 2.

5.4.9.4 Performance of participant 4

Figure 5.10 displays the percentage of correct responses and the number of attempts made to identify the correct items by Participant 4. Following subsections present the results in terms of: a) number of correct responses, and b) number of attempts made to identify the correct responses.

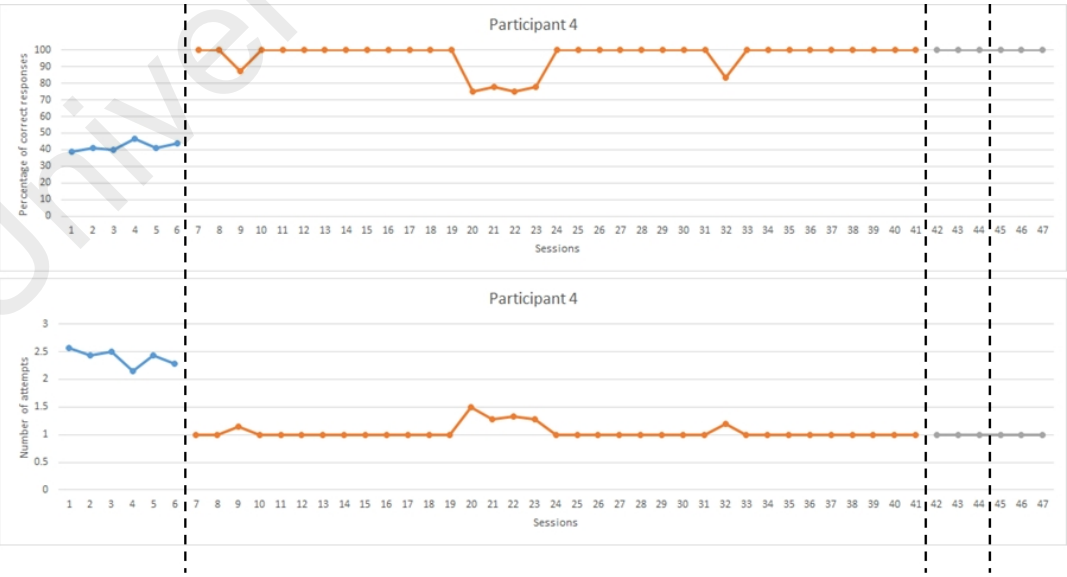

Figure 5.10: Performance of participant 4

*(a) **Correct responses***

The mean performance of the participant during baseline was 42% which shows that participant 4 was facing difficulty to identify the correct items in the start. The use of serious games during intervention brought a lot of improvement in the performance of participant 4 and the performance increased to 96%. The participant had 100% retention during maintenance at the end of week 1 and 2 following withdrawal of intervention.

The results of post-intervention activity game played on the first and second day show that participant 4 correctly identified (46 out of 48 i.e. 95.83%) and (59 out of 61 i.e. 96.72%) birds in each of the three-minute activity games.

*(b) **Number of Attempts***

The mean number of attempts made to identify the correct bird during baseline was 2.4 which was lowered and improved to 1.1 after learning through serious games and it remained almost the same i.e. 1 during maintenance at the end of week 1 and 2.

5.4.9.5 Performance of participant 5

Figure 5.11 displays the percentage of correct responses and the number of attempts made to identify the correct items by Participant 5. Following subsections present the results in terms of: a) number of correct responses, and b) number of attempts made to identify the correct responses.

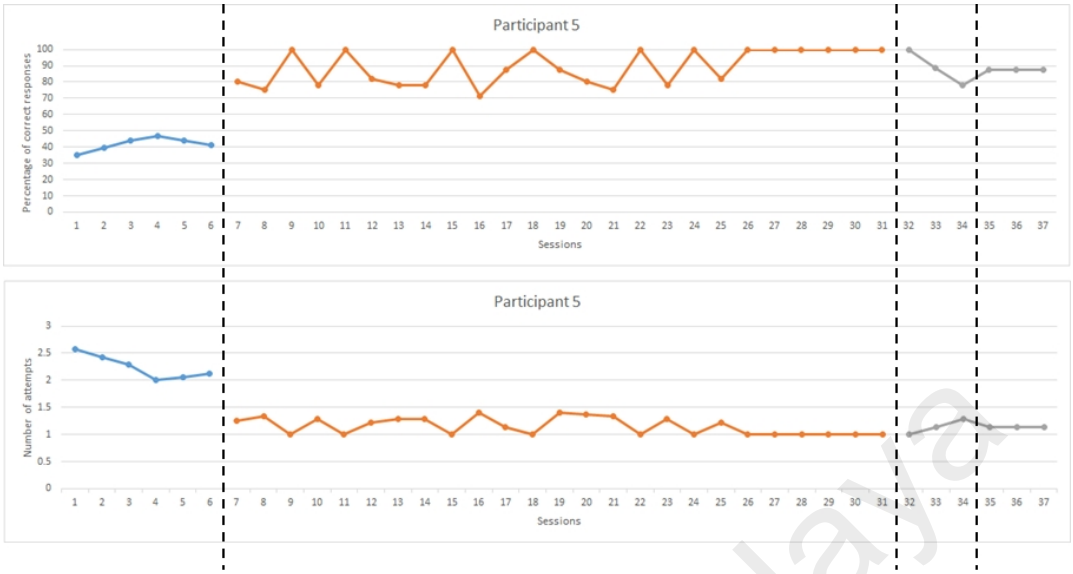

Figure 5.11: Performance of participant 5

(a) ***Correct responses***

The mean performance of the participant during baseline was 42% which is an indication that participant 5 was struggling to identify the correct items in the start. The use of serious games during intervention brought a lot of improvement in the performance of participant 5 and the performance increased to 89%. The participant had 88% retention during maintenance at the end of week 1 and 2 following withdrawal of intervention.

The results of post-intervention activity game played on the first and second day show that participant 5 correctly identified (45 out of 45 i.e. 97.78%) and (45 out of 49 i.e. 91.84%) birds in each of the three-minute activity games.

(b) ***Number of Attempts***

The mean number of attempts made to identify the correct bird during baseline was 2.25 which was lowered and improved to 1.1 after learning through serious games and it remained the same during maintenance at the end of week 1 and 2.

5.4.9.6 Effectiveness

*(a) **Correct responses***

The visual analyses of the correct responses across the participants in Figure 5.7 – Figure 5.11 show that the number of correct answers improved from the average of 53.97% during baseline to 92.57% during intervention i.e. when they were playing serious games for the learning. The participants also had a retention rate of 93.73% during maintenance at the end of week 1 and 2 following withdrawal of intervention.

*(b) **Number of attempts:***

The visual analyses of number of attempts made to identify the correct responses across the participants in Figure 5.7 – Figure 5.11 show that these attempts were reduced from a mean of 1.9 during baseline to 1.11 during intervention and remained the same during maintenance.

5.4.10 Overall performance

Figure 5.12 – Figure 5.14 shows the performance of all the participants in terms of number of correct responses during baseline, intervention and maintenance through clustered column charts. All charts show five columns and a line running through them where each column, in a sequence (from the first column i.e. the leftmost column to the fifth column i.e. the rightmost column), corresponds to an individual participant i.e. from the first participant to the fifth participant. It can be seen in Figure 5.7 – Figure 5.11 that each participant had a different number of sessions during intervention, but 20 sessions were chosen for the analysis of performance in this section as each participant had commonly taken part in the selected sessions. The line shows the average number of correct responses for all the participants in each session. The result suggests that children with autism were able to learn distinguishing birds through the prototype and

identify specific birds when they are asked through a written or verbal question. Their learning of birds improved after using the prototype and they retained the names of the birds they learned after the first and second week once the intervention was withdrawn.

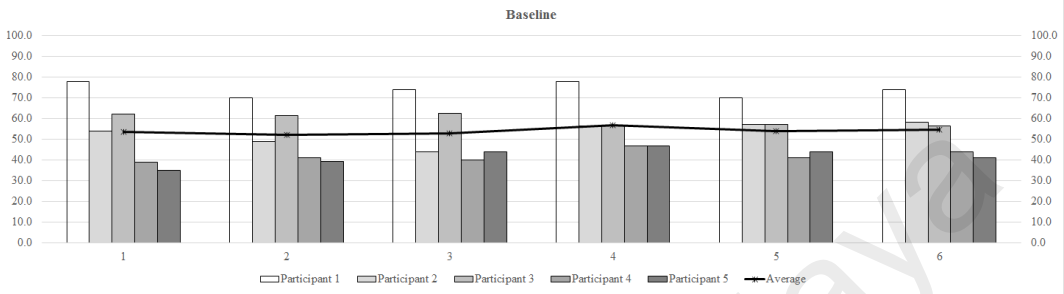

Figure 5.12: Performance of all the participants in terms of number of correct responses during baseline

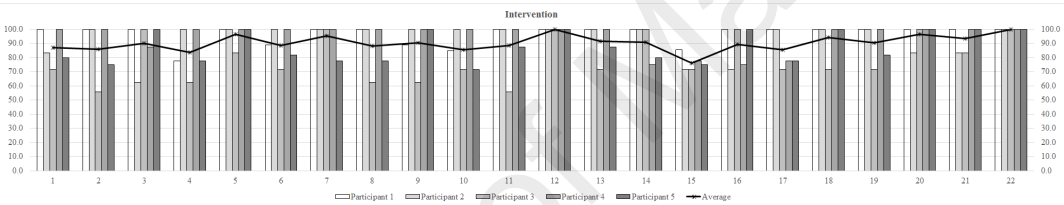

Figure 5.13: Performance of all the participants in terms of number of correct responses during intervention

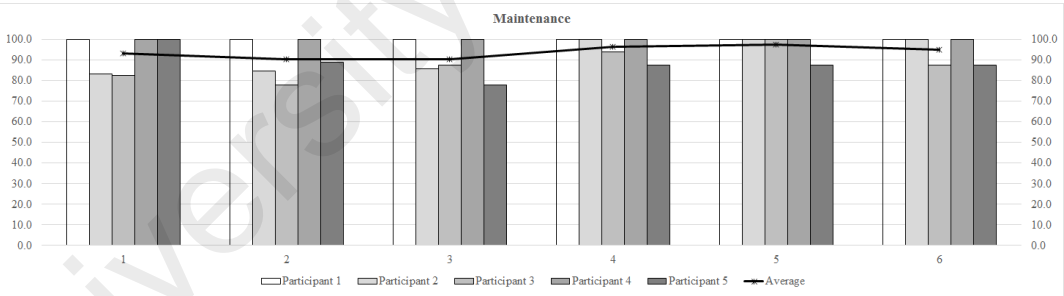

Figure 5.14: Performance of all the participants in terms of number of correct responses during maintenance

Figure 5.15 – Figure 5.17 shows the number of attempts made to identify the correct responses by all the participants during each session during baseline, intervention and maintenance through three clustered column charts. The format in presenting data through columns and a line in each session is the same as of Figure 5.14. The results suggests that as the learning of children with autism improved through the intervention,

their number of attempts made to identify the correct responses was also reduced from baseline to intervention and remained the same in maintenance.

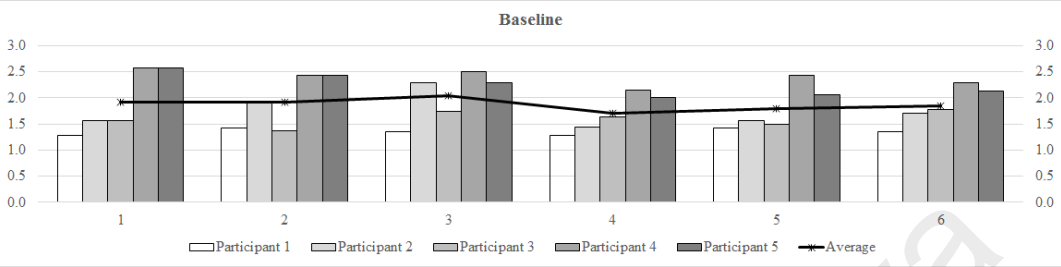

Figure 5.15: Performance of all the participants in terms of number of attempts made to identify the correct responses during baseline

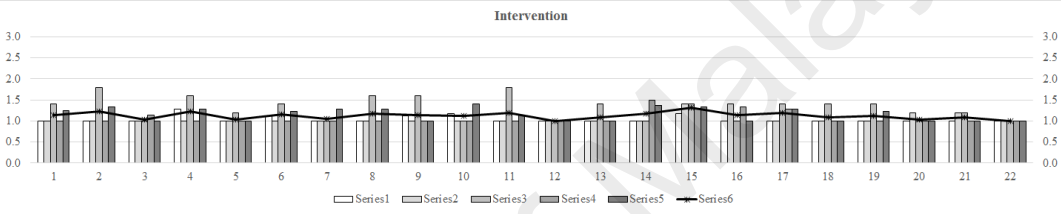

Figure 5.16: Performance of all the participants in terms of number of attempts made to identify the correct responses during intervention

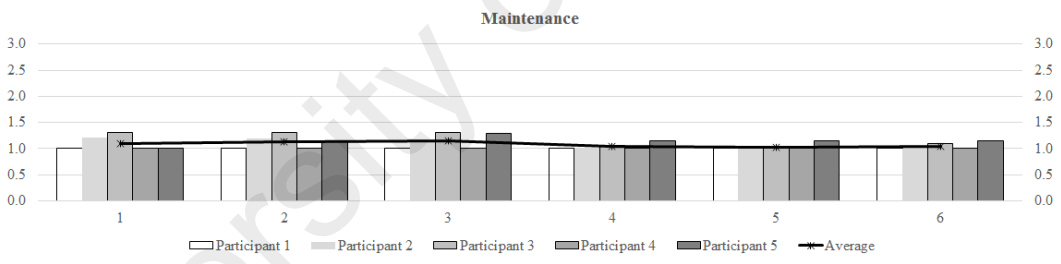

Figure 5.17: Performance of all the participants in terms of number of attempts made to identify the correct responses during maintenance

5.4.11 Discussion

The design of the serious game produced by the expert from which the prototype was developed has:

1. components from ASD perspective that can contribute to the learning of vocabulary among children with autism
2. components from existing frameworks for typical children and typical users that can contribute to various aspects of design.

It is important to highlight how the components from the ASD perspectives contributed in the learning of children with autism. The specific instruction method called discrete trial training (DTT) used in the design provided rigorous learning and practice of each vocabulary item in the category of bird and improved the skill of receptive identification of items. The use of strategies like multimedia instruction provided audio and visual learning, while explicit instruction provided details and multiple exposures of all the birds. The most commonly used modalities were incorporated in the design so that it is easier for the child to interact with the environment of the serious game. This indicates the applicability of the framework to design serious games that can provide effective learning environment for these children to learn vocabulary.

The expert has used fourteen out of twenty components from the framework in the design. This shows that the expert who produced the design was able to read through all the components and their descriptions, understand the relationship between the components and brainstorm about the components that would be required to design serious games for these children. This also shows that the framework can be used by any individuals including game designers and researchers working with these children among others to produce designs for them.

5.5 Summary

This chapter provided an insight on the development of serious game prototype based on one of the designs by the experts presented in chapter 3. The details on the tools used to develop the prototype, its game flow and all the screens are presented. Lastly, the evaluation of the prototype based on SSRD among these children is discussed and the results are presented. The results of the evaluation revealed that the

performance of the children improved after using the serious game prototype and they also retained the vocabulary at the end of first and second week following withdrawal of intervention. It also revealed that the number of attempts made by the children to identify correct responses improved and lowered from baseline to intervention and during maintenance.

CHAPTER 6: CONCLUSION

6.1 Introduction

This chapter discusses the overall work that has been carried out throughout this research. First, it presents the findings in line with the research objectives and research questions. Second, it highlights all the contributions, identifies the limitations of the study and presents the future work that can be carried out using this research.

6.2 Research objectives revisited

This section revisits all the research objectives related to this research.

6.2.1 Research objective 1

The first objective is to identify all the components related to children with autism and serious games that can constitute the serious game design for these children to learn vocabulary. First, the systematic literature review (SLR) was carried out to identify the strategies that have been used to teach vocabulary to these children and computer-based interventions (CBIs) that been developed. The focus of the review was initially on studies related to vocabulary instruction of the reading comprehension; however, due to limited number of studies, the search was further extended and text comprehension instruction was also included. The findings from the SLR lead to the review of autism behaviours, instruction methods, modalities and serious games. The narrative review on autism behaviour revealed various behaviours related to the learning of vocabulary in which these children can face difficulties. Similarly, the narrative review of instruction methods revealed various instruction methods that can be used to teach vocabulary to these children. The SLR was conducted on the modalities and CBIs used in the studies of language comprehension. Due to limited number of studies, the scope of SLR was further extended with the inclusion of studies related to decoding skills as well. The

findings revealed a very limited use of modalities among the studies related to vocabulary; the use of CBIs supporting children in the learning, retention and generalisation of skills. The review of serious games for children with ASD revealed that a number of serious games have been developed to support these children in the learning of various skills. These games have improved the learning of these children; however, these games have not been exploited to provide learning of vocabulary. The strategies, autism behaviours, instruction methods, and modalities are found from the review of literature of children with ASD and learning of vocabulary. These are regarded as components specific to children with ASD.

From the review of serious game, it was found that researchers typically use serious games design frameworks as a support during the entire design process of serious games. This leads to the review of existing serious games design frameworks for children with ASD to identify the components that have been used in the frameworks. This review revealed only one framework and that framework had only used components from four components related to ASD and learning of vocabulary but did not reveal any new component. A quick visual approximation of components found from the framework was performed with the screens of all five games identified by (Watkins, 2015); these games have supported autistic children in the learning of various skills. The visual approximation revealed a few components which were not used in the framework but are common in the games for typical children. Therefore, the review on frameworks for children with ASD was further extended to the review of frameworks for typical children. Another visual approximation of the games identified by the Watkins was performed based on the components found from the frameworks for typical children. This revealed a few more components which are commonly used in serious games for typical users. Therefore, the review of frameworks was further

extended to frameworks for typical users. This further highlighted a few more components which were not found in the previous two reviews. This review also highlighted the use of game-based learning attributes in the framework which leads to the conduct of a review to identify the attributes that can be incorporated in the design of serious games. The review revealed that these attributes are based on theories of learning and theory of psychology. A review of the mentioned theories was conducted and then the attributes were mapped with the theories.

Altogether, a total of 50 components were compiled from the review of literature on ASD and existing serious games design frameworks. These components were processed by grouping similar components together at the intra-frameworks and then at the inter-frameworks which resulted in thirteen components.

6.2.2 Research objective 2

The second objective is to construct a serious game design framework (SGDF) that can be used as a basis to design serious games for children with ASD to learn vocabulary. The components for the framework were identified from the detailed literature as described in objective 1. A three-step process was carried out to construct SGDF: 1) identification of the components, 2) identification of the underlying structure and 3) logical placement of the components on the phases of underlying structure. This leads to the initial version of the SGDF. An iterative approach was used to conduct evaluation based on expert reviews, application test and applicability survey with the academicians, researchers working in the area of serious games, and game designers. The expert reviews involved review of components and their details, relationship between components and placement of components on the underlying structure. The applicability test followed by applicability survey involved designing a serious game

using SGDF. Hence, the proposed framework was effectively refined based on the comments provided by the experts across the evaluations.

6.2.3 Research objective 3

The third objective is to design a serious game proposed version of the SGDF and then develop a serious game prototype based on the design. A design produced by one of the experts from the research objective 2 was transformed into a serious game prototype. An approach of heuristic evaluation was used to identify and fix usability problems in the prototype. In the inexistence of specific set of heuristics to evaluate prototype for these children, a modified set of heuristics was developed as a part of this research to perform evaluation. This set of heuristics was used to evaluate and improve usability of the prototype.

6.2.4 Research objective 4

The last objective of this research is to conduct an experimental evaluation of the serious game prototype and analyse the performance of learning vocabulary among autistic children before and after using the prototype. A single-subject research design was used as a method to perform experimental evaluation of the prototype. The results of the experimental evaluation show that the performance of the children in learning vocabulary improved after using the serious game prototype. This is based on their improvements from baseline to intervention followed by two days of activity games and two tests in maintenance.

6.3 Research contributions

This research has made the following contributions while achieving its individual research objectives.

6.3.1 Systematic literature reviews (SLRs)

Two SLRs were conducted as a part of this research; the contributions from both of them are presented in the following sub-sections.

6.3.1.1 Systematic literature review (SLR) of strategies and computer-based intervention (CBI)

An SLR was conducted to identify the national reading program (NRP)-based strategies of vocabulary instruction (VIN) and text comprehension instruction (TCIN) used, CBI used or developed during the study, and the effectiveness of using CBIs in teaching children with autism. The analysis of studies shows that two among the five strategies of VIN i.e., multimedia methods and explicit instructions, were found to be more commonly used than the other three. On the same note, a question answering strategy among the seven strategies of TCIN was more often used than the others. The use of CBIs as a mode of instruction for reading comprehension improved the learning of the children. This is clearly evident judging from the performance of the children in pre-tests and post-tests of the studies in which CBI was used. The study provided some recommendations in the form of technology-based solutions that could be developed to provide intervention of VIN and TCIN to these children; these solutions were identified based on their use for the intervention of other skills related to autism.

6.3.1.2 SLR of modalities and effectiveness of CBI in learning, generalisation and maintenance

An SLR was conducted to identify modalities used in language comprehension, investigate the effectiveness of CBI using these modalities towards the learning, generalisation and maintenance of information among children with ASD. The last aspect to be explored was to investigate whether the teacher and the CBI together

provide better results in the learning of these children than the situation in which either the teacher or the CBI is used. The findings revealed that the use of modalities in comparison to other skills for ASD is very minimal which creates an opportunity for researchers to explore what are the other modalities that can benefit these children towards the learning of language comprehension. The analysis of the results showed that CBIs improved the learning of these children, allowed them to generalise the information and they were also able to maintain information over a period of time. It also showed that when the CBI is used by the teacher as a support, it provided better results than using either of them alone, and the CBI alone is more beneficial than using the teacher alone. The review provided several recommendations for researchers in terms of modalities, emerging CBIs that can be developed based on information obtained from the other skills of ASD, impact of CBIs on the generalisation and maintenance of information.

6.3.2 Serious game design framework (SGDF) for the learning of vocabulary

The SGDF is one of the key contribution of this research. The game designers and researchers working these children can use SGDF as a basis to design games for these children to learn vocabulary. The framework can provide them support to design serious games in terms of: 1) the components needed from the perspectives of ASD that can contribute in the learning of vocabulary among children with autism, and 2) the components that can contribute to different aspects of the design. This contribution is based on the two contributions in the form of SLRs presented in section 6.3.1 as well as three other contributions, namely autism behaviours, game components, and game-based learning attributes. These three contributions are further described in the following sub-sections.

6.3.2.1 Autism behaviours

A list of autism behaviours has been compiled and divided into four categories namely language comprehension, verbal communication, non-verbal communication and general behaviours based on various sources of the literature. The behaviours associated with vocabulary falls into the category of language comprehension. Although the list is not exhaustive but it can provide a good reference to the researchers and game designers to identify behaviours related to vocabulary that can be targeted in the game to provide intervention for autistic children.

6.3.2.2 Game components

A comprehensive list of components has been compiled based on the review of literature on ASD and the existing serious games design frameworks. The four components namely autism behaviours, strategies, instruction methods and modalities are related to children with ASD and their learning of vocabulary. The remaining components are based on the review of existing serious games design frameworks. These components include desired capabilities, instruction contents, learning outcomes, learning activity, game genre, game mechanics, game dynamics, scene, storytelling, narratives, characters, game-based learning attributes, reflection, user profile, and user achievements. Each component plays an important role in the design of the game and can contribute towards certain aspect of the serious game design for autistic children to learn vocabulary.

6.3.2.3 Game-based learning attributes

A comprehensive list of 33 game-based learning attributes has been compiled based on the existing frameworks and research in which these attributes have been used. These attributes have been classified into learning theories as well as theory of psychology

based on the description and use of attribute. Each attribute from the compiled list can contribute to provide support in the learning and engagement of autistic children within the game environment.

6.3.3 Prototype of serious game for children with autism to learn vocabulary

A prototype of serious game has been developed to show a logical view of the revised version of the framework. The prototype of serious game allows children with autism to learn different categories of vocabulary items through rigorous learning and practice of material. The results of the experimental evaluation show that serious games facilitated these children in the learning of birds in which they were facing difficulty.

6.3.4 Modified set of heuristics to evaluate interactive systems for children with ASD

A modified set of fifteen heuristics has been developed based on the review of existing guidelines to design interactive systems for children with ASD. In this research, this set of heuristics has been used to identify and fix the usability problems in the serious game prototype before this prototype is used by children with autism. This set can be used by the game designers and researchers working on their game design to improve the usability of the prototype.

6.4 Limitations of study

Despite the contributions that have been discussed in the previous section, there are certain limitations of this research which are discussed in this section.

6.4.1 Use of serious game prototype by children with autism

The prototype of serious game was developed based on one of the designs produced by the experts during the applicability evaluation of the SGDF. The expert of the design

focused on one behaviour and eleven categories of vocabulary as an instructional contents. Thus, the prototype can only be used by those children with autism who require support in terms of learning and improvement of the identified behaviour and instructional contents targeted in the design.

6.4.2 Modified set of heuristics

The modified set of heuristics proposed in this research are based on the review of existing guidelines to design an interactive system for children with ASD.

6.5 Recommendations for future work

This section presents some of the work that may provide step forward to extend this research.

6.5.1 Evaluation of SGDF

The framework proposed in this research is a specialised framework as it allows game designers and researchers to target behaviours associated with the learning of vocabulary among children with autism identify a suitable instruction method to teach vocabulary to these children among others. The details of these components can be further enriched so that framework can be utilised and evaluated for various other skills related to these children. The details may include identification of all the behaviours related to the skills to be targeted in the design of serious game. It also requires an identification of all the evidence-based instruction methods that have proven to be effective to provide an intervention to these children for the targeted skills.

6.5.2 Development of new prototypes

For the future prototypes, the researchers can:

1. can target different behaviours in the design of serious games which means that the children who face difficulties in one or more of these behaviours can practice, learn, improve and overcome their difficulties.
2. consider different categories of vocabulary items or vocabulary items that have not been covered in the categories used in the prototype.
3. incorporate more modalities in the serious game and determine its impact on the learning of vocabulary.
4. develop virtual reality-based environment where children are exposed to real world scenarios. For instance, if they are to be taught different food items, they are shown a scenario of one grocery store with different food items placed in different aisles of shelves and they are asked to visit all the aisles in the store and explore the items placed in the shelves.

6.5.3 Extension of modified set of heuristics

The researchers can extend the work on the modified set of heuristics and conduct focused group discussion with experts of HCI and ASD to gather their opinions on the modified set, and evaluate more of the different systems of ASD to determine the effectiveness of the heuristics.

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LIST OF PUBLICATIONS AND PAPERS PRESENTED

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Khowaja, K. and S. S. Salim "A systematic review of modalities in computer-based interventions (CBIs) for language comprehension and decoding skills of children with autism spectrum disorder (ASD)." (Under review in Review Journal of Autism and Developmental Disorders)

Note. The status of "Under review" is based on the time of printing this thesis.