EXPLORING CHEMCAPER IN REINVENTING CHEMISTRY LEARNING

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ABSTRACT

With the emergence of a new generation that lives and breathes on digital technology also come challenges in education. Educators today encounter numerous obstacles in their classroom, and one of those hurdles is how to capture and keep the iGeneration engaged and motivated towards learning for a long time. This widening digital divide has left a major impact on students' diminishing motivation to learn Science and Chemistry, leading to poor performance in examinations and a drop in students enrolling for Science subjects. As document proof shows the iGeneration is wired differently, the main aim of this study is to explore and investigate the possibility of reinventing Chemistry learning using a selected digital role-play game known as ChemCaper. Purposive sampling was used to select the iGeneration sample, which consisted twenty students from an international school and findings of this study showed these students were extremely engaged and motivated to play ChemCaper. The elements of reinvention in Chemistry learning occurred in various forms beginning from the discovery that situated learning occurred through "head fake" whereby students thought they were playing and mastering a digital game without realizing they were actually learning Chemistry. The Chemistry learning in this context includes drawing and naming apparatus, identifying some physical separation techniques, identifying some basic chemical symbols and basic chemical bonding. Another element of reinvention occurred when fifteen of these students (n=19) who had no prior Chemistry knowledge showed moderate to strong attainment of Chemistry knowledge in a short span of two weeks, solely from the continuous active participation of playing ChemCaper. Interview data revealed that most students were able to convert what they played in the game into Chemistry knowledge. It must be stressed that these students are below the formal age of learning Chemistry and that no structured teaching was conducted. Results from the online interactive quiz and focus group interviews also showed that students who were younger could attain equal Chemistry knowledge compared to their older peers. In addition, learning was random and not linear as each student learnt differently based on his or her needs and experience of the game. The final element that connects the dots and translates implicit learning to explicit learning is the importance of scaffolding for the selected iGeneration students.

Keywords: ChemCaper, Digital role-play game (DRPG), iGeneration, reinvention in Chemistry learning, motivation

PENEROKAAN CHEMCAPER DALAM PENCIPTAAN SEMULA PEMBELAJARAN KIMIA

ABSTRAK

Dengan kemunculan generasi baharu yang hidup bergantung pada teknologi digital, juga wujud cabaran dalam dunia pendidikan. Para pendidik hari ini menghadapi pelbagai halangan di dalam bilik darjah mereka, dan salah satu daripada halangan itu merupakan kesukaran menarik perhatian anak-anak “iGenerasi” dan meningkatkan motivasi mereka untuk menumpu perhatian ke arah pembelajaran untuk jangka masa yang lebih lama. Jurang digital yang semakin luas ini menyebabkan kemerosotan dalam motivasi pelajar untuk mempelajari Sains dan Kimia. Justeru itu, prestasi pelajar-pelajar dalam peperiksaan kian merosot dan ini juga menyebabkan mereka hilang minat dalam mata pelajaran Sains. Hasil dari penyelidikan terkini menunjukkan bahawa era digital telah banyak mempengaruhi cara pemikiran anak-anak iGenerasi ini. Maka, matlamat utama kajian ini adalah untuk meneroka dan menyiasat kemungkinan “mencipta semula” (reinventing) pembelajaran Kimia dengan menggunakan “permainan digital main peranan” (digital role-play game) yang dikenali sebagai ChemCaper. Sampel Bertujuan digunakan untuk memilih sampel iGenerasi yang terdiri daripada dua puluh pelajar dari sebuah sekolah antarabangsa. Penemuan kajian ini menunjukkan pelajar-pelajar ini sangat terlibat dan bermotivasi untuk bermain ChemCaper. Elemen-elemen “mencipta semula” (reinvention) pembelajaran Kimia berlaku dalam pelbagai bentuk bermula dengan penemuan “pembelajaran bersituasi” (situated learning) yang berlaku melalui "kepala palsu" (head fake), yang mana para pelajar menyangka mereka bermain dan menguasai suatu permainan digital tanpa menyedari bahawa mereka sebenarnya sedang mempelajari Kimia. Pembelajaran Kimia dalam konteks ini termasuk melukis dan menamakan radas, mengenalpasti beberapa teknik pemisahan fizikal kimia, mengenalpasti beberapa simbol kimia asas dan ikatan kimia asas. Satu lagi elemen “mencipta semula” (reinvention) yg ditemui dalam kajian ini ialah penguasaan ilmu Kimia yang sederhana hingga mahir oleh lima belas pelajar (n = 19) hasil dari “penyertaan aktif” (active participation) berterusan mereka dalam bermain ChemCaper . Di sini, perlu ditekankan bahawa pelajar-peajar ini tidak mempunyai pengetahuan Kimia langsung sebelum ini dan mereka berjaya menguasai ilmu Kimia dalam jangkamasa pendek dua minggu semata-mata dari permainan ChemCaper kerana tiada pengajaran berstuktur dijalankan. Tambahan pula, pelajar-pelajar ini berada di bawah usia formal pembelajaran Kimia. Data dari wawancara telah mendedahkan bahawa kebanyakan pelajar dapat menukar apa yang mereka bermain dalam permainan kepada pengetahuan Kimia (implicit to explicit learning). Keputusan dari kuiz interaktif online dan wawancara kumpulan fokus juga menunjukkan bahawa pelajar yang lebih muda dapat mencapai pengetahuan kimia yang setanding rakan sebaya mereka yang lebih tua. Di samping itu, pembelajaran berlaku secara rawak dan tidak linear kerana pembelajaran setiap pelajar adalah berbeza berdasarkan keperluan dan pengalaman pelajar tersebut dalam permainan ChemCaper itu. Unsur akhir yang menghubung kaitkan pembelajaran dan penterjemahan “pembelajaran tersirat” (implicit learning) ke “pembelajaran yang jelas” (explicit learning) adalah kepentingan “bimbingan” (scaffolding) yang disediakan bagi pelajar-pelajar iGenerasi yang terpilih.

Kata Kunci: ChemCaper, permainan peranan digital (DRPG), iGenerasi, mencipta semula pembelajaran Kimia, motivasi

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LIST OF SYMBOLS AND ABREVIATIONS

DGBL	:	Digital Game Based Learning
RPG	:	Role Play Games
DRPG	:	Digital Role Play Game
ICT	:	Information and Communication Technology
MKO	:	More Knowledgeable Other
ZPD	:	Zone of Proximal Development
PC	:	Playable Character
NPC	:	Non-player Character
TPACK	:	Technological and Pedagogical Content Knowledge

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Have you ever encountered this situation?

You buy a new smartphone and have problems with transferring all your current information and apps from your old phone to your new phone. But, when you hand over the device to your teenager, he quickly figures everything out in 5 minutes and shows you how it is done. He even teaches you how to print from the phone without needing a cable connected to the printer. In another scenario, you download a digital role-play game and accept a quest which requires you to search for items, bond petticles and fight with monsters in your attempt to understand the Chemistry learning that occurs in this game but you have not a single clue how to play the game as you keep hitting an invisible wall or end up going in circles. This frustrates you immensely and you don't understand how kids love to play these games. Again, when you hand the device to your 11-year-old child, she is delighted to have a new game to play and starts asking you questions such as what is the meaning of "Brom-Brom", "Oxyto" as she levels up effortlessly. She quickly teaches you how to navigate through the game and even advises you to fight "the boss" with Cryo because Cryo freezes up the opponent. It seems that your kids are geniuses when it comes to learning, problem solving and discovering new knowledge in the digital world…

These are real life scenarios that has occurred in some homes including the researcher's as the generation today grows up at ease with digital devices, so much so that most toddlers seem to know how to swipe a screen on a smartphone while most young children know how to navigate their way through any digital devices easily to the extent of parents asking their kids for help when it comes to digital devices. All this points to the fact that the younger generations are getting more and more tech savvy and are rightly called digital natives by Prensky (2001a) as they take to all digital devices like fish to water. A more recent description coined by Rosen (2011) and his team of researchers to label this new emerging generation that encompasses children and teens born in the new millennium is the iGeneration. Their love for electronic communication and ability to multi-task effortlessly points to the fact that their brains are wired differently (Berson & Berson, 2010; Buckleitner, 2009; Calvert, Strong, & Gallagher, 2005; Chiong & Schuler, 2010; Couse & Chen, 2010; Kerawalla & Crook, 2002; Lisenbee, 2009; Prensky, 2001; Rideout, Lauricella & Wartella, 2011).

However, with the emergence of a new generation that lives and breathes on technology also come challenges in education. Educators today encounter numerous obstacles in their classroom, and one of those hurdles is how to capture and keep the iGeneration engaged and motivated towards learning for a long time (Blum, 2016; Khan, 2012; Prensky, 2007; Robinson & Aronica, 2016; Rosen, Carrier & Cheever, 2010) as one common complaint is student's inability to pay attention during lessons.

Another concern many educators believe is an obstacle to education is that most schools today are unable to provide optimized learning environments for digital natives to prepare them for the digital workplace of the future causing a disconnect in education (Fullan, 2013; Hattie; 2012; Kelly, McCain & Jukes, 2009; Papert & Markowsky, 2013; Prensky, 2001b, 2007; Rosen, Carrier & Cheever, 2010; Tapscott, 2009). Even Bill Gates (2005) noted that America's high school would eventually be obsolete, as schools are not training kids of today to fill the workforce of tomorrow. This concern is also evidenced by US statistics that show a high number of student dropouts from high school (Cullen, Levitt, Robertson & Sadoff, 2013) with leaders in education stating that the failure of American schools is due to the mismatch in pedagogy styles as digital technologies have conquered the minds of our young generation, influencing the way they behave, think and learn.

It is a known fact that interest and motivation play a crucial role in learning (Dewey, 1938; Hidi, 1990; Krapp & Winteler, 1992; Larson, 2000; Maehr & Meyer, 1997; Olson, 1997; Palmer, 2007; Pintrich et al., 1993; Pugh & Bergin, 2006; Schiefele, 1991) and numerous research have shown that these digital natives learn differently and have problems sitting passively for hours while teachers dominate the class teaching. These findings are substantiated by the fact that the average college student spend fewer than 5,000 hours of their lives reading but more than 10,000 hours playing video games and a further 10,000 hours on their digital cell phones (Prensky, 2001b).

The scenario in Malaysia is not much different with the number of Internet users totaling over 24.1 million, which accounts to 77.6% of total Internet penetration (Malaysian Communications and Multimedia Commission, MCMC, 2016). From this figure, over 72% are aged between 7 and 35 and in a study conducted by CyberSAFE in Schools National Survey (2013), it was found that about 51% of the participants reported playing games online, with more than a third (35.6 per cent) of the respondents spending between one and 12 hours a week in cyber cafes. Another recent report compiled by the United Nations Children's Fund (UNICEF) Malaysia (Pawelczyk & Kuldip Kaur, 2014) showed that the influence of online gaming in Malaysia is evident with 80% of the 1,200 study participants surveyed (aged 14–16) indicated they played online games. The report also mentioned that the hugely popular game Candy Crush Saga had over 1.2 million fans from Malaysia. With such significant hours spent on the Internet and online games, one wonders how much time is allocated for studying.

1.2 Problem Statement

According to Blum (2016), this old classroom model is widening the gap between the way kids are taught and what they actually learn; stumping students' creativity and motivation to learn, and in short making children hate school. This widening digital divide has also left a major impact on students' diminishing interest and motivation to learn Science in general and Chemistry in particular as teachers strive to teach using PowerPoint presentations as their mode of modern technology use while students require more immersive environments that would capture their attention (Devlin, Feldhaus & Bentrem, 2013; Howe & Strauss, 2000; Levin & Arafeh, 2002; Prensky, 2001b; Raman & Abdul Halim, 2013; Samuel & Zaitun, 2007; Stofflett, 1998; Woempner, 2007; Zoller, 2000). Data from countries like US, UK, Ireland, Africa and Western Europe countries also show the lack of interest and motivation in learning Science among students with studies in the US showing the global position of STEM has declined despite efforts to push advanced learning

(Rapini, 2012; The President’s Council of Advisors on Science and Technology, 2010).

In Malaysia, research also shows students lack the interest to learn science in general (Boo, 2015; Chew, Noraini & Leong, 2014; Kang, 2013; Kong, 1993; Ministry of Education, 2012). This of course includes Chemistry, a subject which students find difficult to grasp (Coll & Treagust, 2001; Johnstone, 1991; Ozmen, 2004; Taber, 2002) as numerous studies also show that students lack interest and motivation to study Chemistry (Farhana & Zainun, 2013; Muzammila, Johari & Murad, 2014; Woldeamanuel, Atagana & Engida, 2014). Moreover, reports show a significant drop in student numbers who qualify to study science due to poor performance in national examinations and international assessments (Boo, 2015). The fact that only 21% of those studying in upper secondary chose to study science subjects in 2014, (Spykerman & Lee, 2015) is cause for concern as national target of science and technology to arts ratio is set at 60:40 (Ministry of Education, 2012).

In an era where digital media dominates the society, parents are concerned with children spending significant amount of time on various modes of digital devices. This is evidenced by a U.S. study done by the Kaiser Family Foundation (2010). Results from the longitudinal 10-year study showed a marked increase in the amount of time spent by tweens (age 8 to 12 years old) and teens (13 to 18 years old) on the use of digital media for all sorts of activities with the exception for reading. In another study conducted by Common Sense Research Study (2012), children spend up to 9 hours daily on various activities on the Internet after school, mostly playing games. With the iGeneration focusing much of their time, energy and concentration on digital games, it is no wonder that parents and “old school” teachers become more worried than ever that time spent on learning is compromised. These concerns are further echoed by educationists of the future (Blum, 2016; Khan, 2012; Robinson & Aronica, 2016) who disagree with the current didactic education system that pushes students together in age-group batches with one-pace-fits-all curricula (Khan, 2012). This is especially true when Rosen, Carrier and Cheever (2010) and Christakis (2014) have documented proof that the brains of the iGeneration are wired differently.

Chemistry as a Science subject has generally been documented as difficult and causing students to lose interest (Aikenhead, 2003; Farhana & Zainun, 2013; Johnstone, 2000; Taber, 2002). In order to provide meaningful Chemistry learning for the generation today, chemistry educators must provide the most appropriate method of education to fit into the learning styles of these digital natives to meet their needs. Research from various fields shows that play is a powerful mediator for learning (De Freitas & Griffiths, 2007; Montessori & Carter, 1936; Piaget, 1959; Vygotsky, 1932; Zimmerman, 2003) and virtual environments such as those found in Digital Role-Play Games (DRPG) provides the engagement and motivation to develop deeper learning and higher order skills (Chen, Wong & Wang, 2014; Dede et al, 2005; Gee, 2007; Holzinger, Kickmeier-Rust, & Albert, 2008; Lassiter et al., 2001; Mitchell & Savill-Smith, 2004; Prensky, 2006; Robertson & Howells, 2008) for our young generation.

Although there is a growing body of literature (Chen, Wong & Wang, 2014; Connolly, Stanfield, & Hainey, 2011; Dickey, 2007; Dominguez et al., 2016; Hallford & Hallford, 2001; Randi & de Carvalho, 2013; Rankin, Gold & Gooch, 2006; Tsai, Yu & Hsiao, 2012) conducted on the use of DRPG in education, at the point of writing the researcher found only one that focuses on using DRPG in teaching Chemistry with the learning of Chemical Formula as the research topic (Chen, Wong & Wang, 2014). Participants of that study were high school students of the same age cohort and were required to have prior Chemistry knowledge before playing the game. In addition, the DRPG was only adopted during the research period and there was no evidence of continued play after the research period. To top it off, the researcher did not find any reports on the possibility of using DRPG to educate younger children who have not been formally taught Chemistry nor was there any studies to look into teaching Chemistry across a range of different ages using DRPG way before they come of age to learn the subject formally.

In order to investigate claims by researchers (Collins & Halverson, 2009; Horn, 2015) that digital revolution has helped to propel the trend of accelerating students' learning based on skills and not age, upper primary school students who have not been exposed to Chemistry learning were the most suitable. This cohort would have no prior knowledge in Chemistry learning but have sufficient command of the English language to understand the game. By assessing if students of the iGeneration can truly learn Chemistry beyond their age using a selected DRPG found in the industry, it may just help to change the way educationists think how students should learn and reinvent the learning of Chemistry. It will also provide more empirical evidence that the iGeneration students are truly rewired differently and can learn beyond their ages using digital technologies. Thus, this study explored one such DRPG, known as ChemCaper.

1.3 Rationale of the Study

Although extensive research has been conducted on a myriad of pedagogical approaches on how best to educate the iGeneration with some positive results, it is unimaginable how students will be learning a decade from now with innovations in science technology growing at exponential rates. With numerous studies suggesting a need to revamp the curriculum to equip the next generation with 21st century skills (Fullan, 2013; Hattie, 2012; Kelly, McCain & Jukes, 2009, Papert & Markowsky, 2013; Tapscott, 2009), new learning styles such as using DRPG in game-based learning should be given serious consideration as recent research have provided both theoretical and empirical support that children today live and breathe on digital games (Garris, Ahlers, & Driskell, 2002; Johnson et al., 2011; Levine, 2006; Rapini, 2012; Rees, 2015; Rooney, 2012; Squire, 2011).

From the experiences of the researcher as a Chemistry teacher and numerous discussions with parents and other Chemistry teachers (Choong, Oh, Renu, Tay, et al., personal communication, January – June, 2016; Wiggins, 2013; Wright, 2013), one common agreement that arises is the knowledge that students are inattentive, feel bored and have problems sitting for long hours daily in school learning. However, these very same students would suddenly come alive and be animated when someone pulls out a device with games or when digital games are being discussed (Choong, Oh, Renu, Tay, et al., personal communication, January – June, 2016; Hu, 2011).

Moreover, these students are very quick to learn the game strategy and can explain extensively how to defeat a video game Boss (chief villain) in one sitting as well as remember all the ins and outs of these complex game effortlessly. These keen observations on how students behave towards game have drawn the researcher into exploring how learning occurs through playing these games. Besides that from extensive readings, umpteen research (Barko & Sadler 2013; Chen, Wong & Wang, 2014; Cheng, Lin & She, 2015; Devlin, 2011; Dominguez et al., 2016; Farber, 2015; Gazzard, 2011; Gee, 2003, 2007; Gillispie, Martin, & Parker, 2010; Hawkes-Robinson, 2011; Prensky, 2001b, 2008; Robertson & Howells, 2008; Sedig, 2008; Squire, 2011; Tapscott, 2009; Tsai, Yu & Hsiao, 2012; Van Eck, 2006, 2015) have shown a link between motivation, cognitive achievement and digital game-based learning (DGBL) including digital role-play games (DRPG).

Advocates of Digital Game Based Learning (DGBL) endorse using digital DRPG to inculcate skills important for the future, as it is in every way immersive, captivating and filled with the opportunity of learning through experience by completing a mission or challenge given in the game. In an extensive study conducted by the Federation of American Scientists, the Entertainment Software Association, and the National Science Foundation (2005), many skills such as planning, problem solving, being resourceful and creative thinking were inherent qualities in the game that were sought after by employers.

1.3.1 The Future of Chemistry Education

As leading researchers document proof that the iGeneration are wired differently, with toddlers mastering the use of an iPad effortlessly while adults struggle with the very same device (Christakis, 2014; Prensky, 2007; Rosen, Carrier & Cheever, 2010; Tapscott, 2009), the researcher believes that perhaps the learning of Chemistry using DRPG should not be age related as what is being practiced in the current education curriculum. In fact, there is documented proof to substantiate the idea that students should advance in school based on skill and not age (Collins & Halverson, 2009; Horn, 2015), with Richard Williams, also known as Prince EA (Williams, 2016) producing a video to show that the education system has not changed in the last century and further questions the didactic teaching methods of today. Hence, if we are to embrace the future and move on with an open mind on how innovations can change our way of thinking, learning and living, then the shift from a didactic instructional model to a learner-centred model, focusing on the potential of learning to cut across age barriers using DGBL such as DRPG need to be implored and explored further to understand how it can capture interest, motivate and create satisfaction while providing both implicit and explicit learning to our young learners. This makes the researcher wonder how the education system will be like in the next few decades if such progressive changes were to happen.

1.4 Aim of the Study

As playing games can be taken to being akin to breathing for the iGeneration, the main aim of this study was to explore and investigate the reinvention of Chemistry learning by exploring how selected students who have not been formally introduced to Chemistry learning are able to learn Chemistry through the playing of a selected DRPG with minimum facilitation by the teacher. The selected DRPG is ChemCaper (refer to Definition of Terminologies), which is the first Chemistry adventure game in the games market. This study also aimed to investigate if learning can indeed occur based on skills and not age.

1.5 Research Objectives

Based upon the problem statement of the research, the research objectives of this study were:

1. To explore the motivation of the selected iGeneration students to learn Chemistry using ChemCaper.
2. To evaluate the Chemistry learning attained by the selected iGeneration students who have not been formally introduced to Chemistry curriculum after playing ChemCaper.
3. To describe the 'reinvention' in Chemistry learning from playing ChemCaper.

As data was collected and analysed from the pilot study, the researcher found a need to tweak the online interactive quiz assessment and the focus group interview questions. In addition, an emerging research objective was also discovered and added to investigate the importance of scaffolds to support students' development as posited by Hattie, 2009; Marzano, Pickering, and Pollock, 2001; and Sousa and Tomlinson, 2011. The fourth research objective added is:

4. To investigate the importance of scaffolding for the selected iGeneration students.

1.6 Research Questions

1. How is the motivation of the selected iGeneration students in learning Chemistry using ChemCaper?
2. What Chemistry knowledge has the selected iGeneration students attained after playing ChemCaper?

3. What is the ‘reinvention’ in Chemistry learning among the selected iGeneration students when they learn Chemistry from playing ChemCaper?

From the emerging research objective added in the above section, the corresponding research question added is:

4. How does the presence of scaffolds affect the dynamics of learning for the selected iGeneration students?

1.7 Definition of Terminologies

The following are the definitions of terms used in this study:

1.7.1 iGeneration:

This term refers to the Internet generation (also known as the Net Generation) and is a subset of the term digital natives, coined by Prensky (2001a). It is used to describe the generation of children who are highly connected to popular digital technologies, like the iPhone, iPad, iTunes, iTouch and so on. They are defined by their need to use media, communicate electronically and multitask with digital devices (Rosen, 2011). The iGeneration involved in this study is part of the sample population from Generation Z (children born from year 1996 to 2009), which will be limited to students aged 10 to 12 years old for the purpose of this study.

1.7.2 Digital Role-Play Game (DRPG)

Role-play games (RPG) are games where players assume the roles of fictional characters engaged in adventures. Players will take responsibility in acting out these characters. With the digitization of games, RPGs are now known as digital role-playing game (DRPG). It is a genre of video game where the player controls a fictional character (or characters) and goes on a quest in an imaginary world. As the RPG in this study is digital, hence both RPG and DRPG refer to the same thing. The DRPG selected in this study is ChemCaper.

1.7.3 ChemCaper

ChemCaper has been acknowledged as the first Chemistry DRPG in the world that introduces players to the foundations of Chemistry learning. It is a single player RPG, whereby the player controls a fictional character, called Roub (after the element Rubidium) on a mission. The mission involves fighting battles with alycons (monsters) and receiving rewards such as orbs (atoms), berries (potions), cards, spell books, points and gold. The rewards received are used to craft potions and make petticles to be more equipped when fighting the “Boss”. In the process of playing the game, the player learns to plan and strategize, besides learning about Chemistry. The components of Chemistry learning include tracing of apparatus, conducting physical separation techniques and chemical bonding. A detailed description of ChemCaper has been included in the methodology chapter.

1.7.4 Chemistry Learning based on ChemCaper

In this study, the Chemistry learning for students aged 10 years old to 12 years old is bound to the basic Chemistry content found in ChemCaper. The reason for this boundary lies in the fact that these students have no prior knowledge to Chemistry. Moreover, no Chemistry teaching will be conducted except for what they learn in the game. This means that all Chemistry learning by the participants occur from the game. The areas of Chemistry learning covered in this game include familiarizing with Chemistry terminology and apparatus, remembering some chemical symbols and formulae for elements and compounds, practicing to observe certain physical processes in Chemistry through experiments, exploring and explaining basic chemical bonding, practicing scientific thinking such as collecting, evaluating, analysing and applying information and also practicing to understand and explain chemistry phenomenon in nature.

1.7.5 Motivation

Motivation is defined as the internal state that provides the energy and directs our attention and focus towards achieving certain goals (Krapp, 1999). According to Pintrich (2003), motivation towards learning may arise from intrinsic or extrinsic factors. Extrinsic motivation can arise from factors such as praise, rewards, encouragement and support while contributors to intrinsic motivation include determination, self-efficacy, confidence and even interest.

As Dewey (1913) saw interest as the main motivating factor in learning and Krapp (1999) defined interest as the special relation between a person and a specific content domain or area of knowledge. Hence, situational interest is investigated under the umbrella of exploring motivation in this research study. Situational interest is defined as interest that arises spontaneously due to environmental factors such as task instructions or an engaging game (Schraw, Flowerday & Lehman, 2001). Situational interest leads to interest-oriented engagement, which is an intrinsic motivational force for the player in a digital game. Feelings to show interest include joy, pleasant tension, or total immersion in the activity in the sense of Csikszentmihalyi's "flow" experience (1990). According to Csikszentmihalyi, “flow experience” is an optimal experience of feeling deep enjoyment and exhilaration as a result of an activity that engages a person completely to the point that time and emotional problem cease to exist. The characteristics of “flow experience” include feeling alert, in effortless control, strong, unselfconscious and at the peak of their abilities. The flow experience will be described in the present study.

1.7.6 Reinventing Chemistry Learning

The reinvention of Chemistry learning for this study looks at how students learn Chemistry through non-conventional pedagogy using a DRPG. Chemistry learning takes a different approach, as students are not subjected to structured classroom mode of learning.

1.8 Significance of the Study

This study started out with the intention of providing a greater understanding about how the iGeneration students learn while playing digital games especially with the vast amount of time these children spend on digital games. Results collected have not disappointed the researcher as rich data collected indicated that the iGeneration is wired differently as their learnin style are completely unconventional. Hence, this research can be a possible small stepping stone for future research especially in Malaysia to understand the learning styles and needs of the iGeneration and to help them use their gaming time in a more structured manner to maximize learning while gaming.

As this study using DRPG in education is a first of its kind to be conducted in Malaysia, the results will also provide a better insight to teachers and educators on the learning styles of this future generation and what motivates them to learn. With the insight gained, it is hoped that teachers will change their approach of educating the next generation in line with the learning styles, not just in the subject of

Chemistry specifically but in education as a whole in order to draw students back towards the love of learning Chemistry and perhaps the other Sciences too. ChemCaper may also be considered as an option in play-based learning.

Results from this study also showed that students can learn based on skills and not age, especially with the use of technology. Therefore, these results could be used to assess whether education and the knowledge of Chemistry can be introduced based on skills and not age. Another significance of this study would be the possibility of introducing Chemistry learning and eventually other subjects to younger students through situated learning with the use of technology like DRPG. Obtaining local empirical statistics to explore the use of DRPG in Science education can be used as a springboard to conduct further research into education based on skills. In conclusion, the Ministry of Education, State Educational Department and District Educational Office can use the results of this study to conduct further research into the possibility of revamping and reinventing their curriculum for the 21st Century learner.

Finally, the findings of this study might put to rest the fear of parents that their child might be wasting precious time on digital games. Hopefully, parents might have no qualms to allow their child to play digital games with educational content for hours on end in the future as these children are growing in an era where the world has gone digital. However, that being said, this game has shown the importance of having teachers as facilitators to guide and motivate students along the right path of learning.

1.9 Limitation of the Study

This study would have actually benefitted from a larger sample of participants. However, due to the negative perception of digital games being a waste of time and energy, feedback from interested students showed that many parents were apprehensive to allow their child to participate in this study. Moreover, due to the young age of the participants, it was difficult to obtain parental consent, as parents wanted to be sure their child would actually benefit from participating in the study. This resulted in many disappointed students who were not allowed to participate in this study due to parental non-consent.

Another limitation to this study was the fact that many students could not commit to a two week long research period as students were required to stay back after school hours everyday for at least an hour. Many students were also loaded with after school activities, including tuitions and were unable to join due to their hectic schedule. To ensure that this limitation did not hinder the results of this study, multiple sources of data were collected for triangulation in this qualitative study.

1.10 Chapter Summary

Our world has evolved into one where technology has become an integral part of our daily life. This generation that was born in the 21st century knows nothing else but to use technology in their every waking and even sleeping moment. Hence, this reliance on technology has brought forth a generation that has lost its interest in the traditional pedagogical methods. In addition, there has been a steady decline in interest towards Science in general and Chemistry in particular. Besides that, industry players and educationist predict that the current curriculum will not be able to equip the next generation to fill the jobs available in the future. With all these concerns to consider, researchers have been looking at how technological advancements can hold the interest of students and keep them motivated to learn, while providing them with 21st century skills to thrive in the future. The solution seems to point towards bringing education to the place where students spend most of their time on, and that is digital games and numerous studies have been conducted to show theoretical and empirical support on the benefits of digital games in education.

With this in mind, the researcher sought to investigate how ChemCaper, which was developed to be the first Chemistry DRPG to cater for the needs of the iGeneration could reinvent Chemistry learning. Hence, it would be interesting to study the effect of this game on the selected iGeneration students. Another aspect that should be noted is the ability of younger children to master digital games effortlessly. As research shows that these younger iGeneration children are wired differently, it would be interesting to understand how they learn from playing digital games and explore the possibility of ChemCaper, the selected DRPG cutting across age in its ability to deliver both implicit and explicit learning of Chemistry.

A detailed literature review given in chapter two suggests the need to change our approach in educating the next generation while chapter three mapped out the concepts of this research study and the underpinning theories in educating the iGeneration differently. Chapter four gives a detailed account on how this study was conducted and the data collected to investigate the research problems. The findings and analysis of the research discussed in chapter five attempts to answer the research questions posed. Finally the conclusion and implications of the study is presented in chapter six.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In a world that has gone digital, technology has impacted every aspect of life. All these point to the fact that the world is evolving at an exponential rate and yet, education especially in Malaysia seem to be moving at snail's pace. This gap could be the reason why students are bored and disinterested in the classroom. With world reports stating that daily media use among children have increased dramatically to over 7 ½ hours on various digital media while reading remains at only 25 minutes daily (Kaiser Family Foundation, 2010), it is evident that the current didactic educational methods will not interest and motivate the iGeneration into learning and eventually equip them in the future work force. That being said, educators must tread carefully to ensure learning is optimized in the medium that appeals most to the iGeneration.

2.2 21st Century Education and the iGeneration

2.2.1 The Requirements of 21st Century Education

We are living in the 21st century, a world that is growing at an exponential rate. The digital universe has grown by 1000% in the last 5 years and according to a survey conducted by EF Explore America (15 March, 2012), many of the top jobs in

2012 did not exist 10 years ago. This exponential growth is affecting the global economy considerably especially the service sector that is globally interconnected and constantly emerging as these industries have less centralized decision-making process and depend heavily on information sharing, team networking and flexible working arrangements.

The United States Department of Education Office of Planning Evaluation and Policy Development (2010) states that students need to have a well-rounded education in order to contribute as citizens and to thrive in a global economy. In order to meet these needs, various well known educational institutions (American Association of Colleges for Teacher Education, AACTE, 2010; International Society for Technology in Education, ISTE, 2007; National Council for Accreditation of Teacher Education, NCATE, 2008; Partnership for 21st Century Skills, P21, 2009) have compiled their individual guidelines with a list of skills needed by students to succeed in this global economy. Although some discrepancies exist among the institutions (Table 2.1), common skills that all institutions agree students require include creativity and innovation, communication and collaboration, critical thinking and problem solving besides having initiative. Other skill that AACTE (2010) and P21 (2009) agreed upon include having flexibility and self-direction besides the core skills required to meet the needs of the future workforce. In addition, students also need to use technology effectively and be conversant with digital tools and technology such as computers and software, mobile phones, online communication to thrive (AACTE, 2010; P21, 2009; Williams, Foulger & Wetzel, 2010). The Committee on Workforce Needs in Information Technology (2001) adds developing students' cognitive abilities of logical thinking, problem solving, analysis, careful observation, and data management to the list of needed skills. Other more specific skills such as decoding, ICT (Information and communication technologies) and media literacy as well as creating content through a variety of media would also provide the extra edge (Burkhardt & Schoenfeld, 2003; Kist, 2003).

Table 2.1

21st Century skills needed by four major educational institutions

AACTE	ISTE	P21	NCATE
Creativity & innovation	Creativity & innovation	Creativity & innovation	Creativity & innovation
Depending on information sharing & team networking	Communication & Collaboration	Communicate & collaborate	Communication & collaboration
	Research & Information Literacy	Find information quickly	
Critical thinking	Critical thinking & problem solving	Critical thinking Solve problems	Critical thinking Problem solving
	Digital citizenship		Cross-cultural skills
	Technology concepts	Use technology effectively	
Self-direction		Self-direction Having initiative	Having initiative
Flexible working arrangements		Being flexible Adaptable	Life and career skills such as flexibility
Decision making		Leadership & responsibility	Leadership

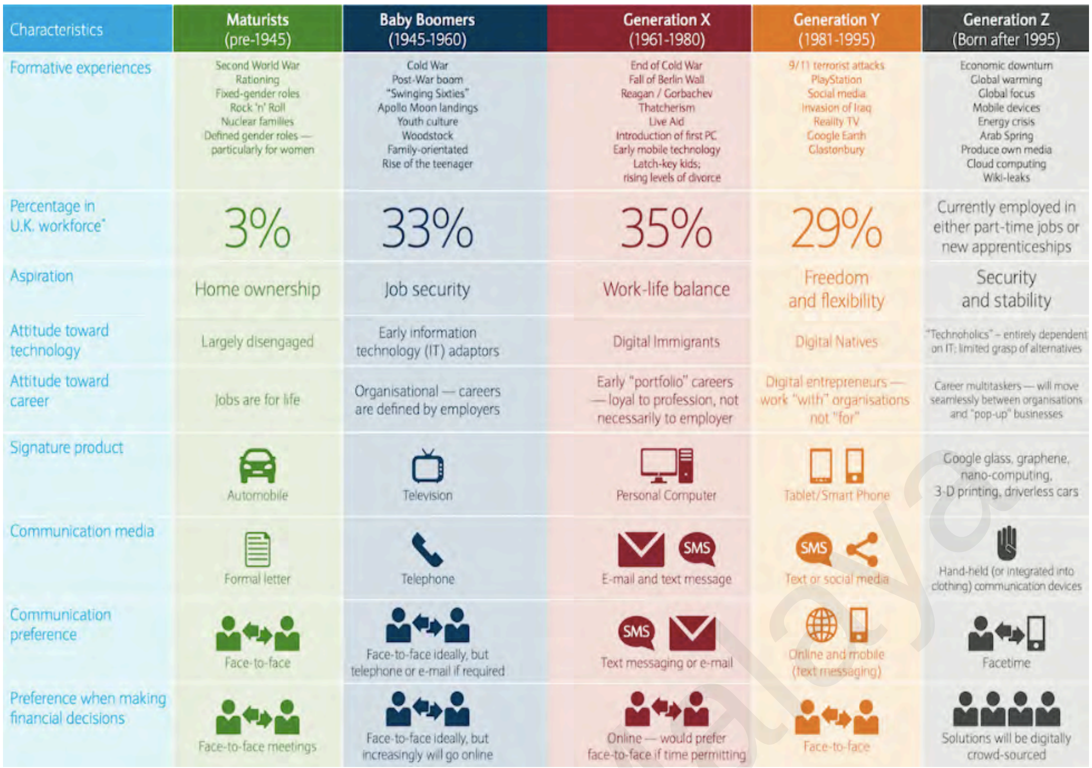
As the education needs for the 21st century learner evolve, so must the roles of teachers to meet the needs of their student. No longer would the traditional role of planning and delivering instruction, assessing student learning and managing classroom be sufficient. To prepare our future generation, significant changes in the teaching and learning practices are also needed, whereby the roles of teachers must evolve to become innovators, mentors, entrepreneurs, motivators and illuminators to prepare students with 21st century educational skills which include creativity, problem solving, cultural awareness, innovation, communication, productivity, leadership traits, responsibility and accountability.

One crucial factor that teachers need is to widen their knowledge base to include the ability to use technology as the central role in their pedagogy to create an active classroom for students. In other words, teachers need to be effective technology designers as the emphasis on teachers' technological-pedagogical content knowledge (TPACK) is becoming imperative. Teachers also need to be effective facilitators to provide scaffolding to support students' development; instructors and motivator to design, deliver and motivate students who learn in various ways and at different rates (Hattie, 2009; Marzano, Pickering, & Pollock, 2001; Sousa & Tomlinson, 2011). Furthermore, Kingsley and Unger (2008) felt that teachers need time to reflect on giving up some aspects of their authority in the classroom, and envision the educational possibilities that the new literacies create.

2.3 Welcome to the iGeneration

According to Tolbize (2008), when members of a group are born and living at about the same time, they share significant life experiences that influence their thoughts, values and behaviours at critical developmental stages. Hence, they would be classified into the same generation. Grouping into age cohorts gives researchers a way to understand how different formative experiences interact with the life-cycle and aging process to shape people's view of the world (The Pew Research Center, 3 September, 2015). In the past, generations are defined biologically based on a span of around 20-25 years, which is the average age between the birth of parents and the birth of their offspring. However, two decades is considered too broad a generational span today as cohorts are changing so quickly in response to new technologies, changing career and study options and shifting societal values (McCrindle, 2011). So today, generations are better defined sociologically based on social markers such as values, beliefs, life style, conditions and technology, besides events and experiences that cut through global, cultural and socioeconomic boundaries. In other words, boundaries are no longer drawn by birth cohorts but more on how social media and online technologies have influenced a young generation that assesses the same websites, watches the same movies, downloads the same songs and are being influenced by the same cultures and brands.

Although there appears to be variations on the exact timeline when a generation ceases and another generation begins, one common consensus among generational experts are the characteristics of each generation. One renowned authority that best describes the characteristics of each generation is McCrindle (2011) in his book entitled "Generations Defined. The ABC of XYZ". Based on his research, McCrindle has classified the generations into Builders (pre-1945), Boomers (1945 – 1964), Generation X (1965 – 1979), Generation Y (1980 – 1994) and Generation Z (1995 onwards). In September, 2013, the Barclays, UK commissioned Dr. Paul Redmond, another leading expert in generational theory to conduct both quantitative and qualitative research to understand the characteristics and fundamental needs of each generation, and how to meet the needs their needs better. From a report produced by Barclays (2013), chart 1 shows an overview of the working generations. In this chart, Builders is also known as Maturists.



Characteristics	Maturists (pre-1945)	Baby Boomers (1945-1960)	Generation X (1961-1980)	Generation Y (1981-1995)	Generation Z (Born after 1995)
Formative experiences	Second World War Rationing Fixed-gender roles Rock 'n' Roll Nuclear families Defined gender roles — particularly for women	Cold War Post-War boom "Swinging Sixties" Apollo Moon landings Youth culture Woodstock Family-orientated Rise of the teenager	End of Cold War Fall of Berlin Wall Reagan / Gorbachev Thatcherism Live Aid Introduction of first PC Early mobile technology Latch-key kids; rising levels of divorce	9/11 terrorist attacks PlayStation Social media Invasion of Iraq Reality TV Google Earth Glastonbury	Economic downturn Global warming Global focus Mobile devices Energy crisis Arab Spring Produce own media Cloud computing Wiki-leaks
Percentage in U.K. workforce*	3%	33%	35%	29%	Currently employed in either part-time jobs or new apprenticeships
Aspiration	Home ownership	Job security	Work-life balance	Freedom and flexibility	Security and stability
Attitude toward technology	Largely disengaged	Early information technology (IT) adaptors	Digital Immigrants	Digital Natives	"Technoholics" – entirely dependent on IT; limited grasp of alternatives
Attitude toward career	Jobs are for life	Organisational — careers are defined by employers	Early "portfolio" careers — loyal to profession, not necessarily to employer	Digital entrepreneurs — work "with" organisations not "for"	Career multitaskers — will move seamlessly between organisations and "pop-up" businesses
Signature product	Automobile	Television	Personal Computer	Tablet/Smart Phone	Google glass, graphene, nano-computing, 3-D printing, driverless cars
Communication media	Formal letter	Telephone	E-mail and text message	Text or social media	Hand-held (or integrated into clothing) communication devices
Communication preference	Face-to-face	Face-to-face ideally, but telephone or e-mail if required	Text messaging or e-mail	Online and mobile (text messaging)	Facetime
Preference when making financial decisions	Face-to-face meetings	Face-to-face ideally, but increasingly will go online	Online — would prefer face-to-face if time permitting	Face-to-face	Solutions will be digitally crowd-sourced

Figure 2.1: An overview of the working generations. Retrieved from a summary of talking about my generations: Exploring the benefits engagement challenge by Barclays, 2013

With the rapid development of technology and the influence of Internet, the characteristics of generation Y have been stretched past 1999 and blurred. Don Tapscott uses the name Millenials for this generation due to the impact of Internet in their lives. Based on a more recent finding of another researcher, Larry D. Rosen (2011), a separate generation has been discovered, known as the iGeneration. The "i" represents the types of mobile technologies such as the iPhone, iPod, Wii, iTunes and also the fact that these technologies are mostly "individualized" in the way they are used. This new generation encompasses children and teens born in the new millennium and are defined by their use of technology and media as well as their love of electronic communication and need to multitask. Studies conducted by the George Marshall Applied Cognition Laboratory (Rosen, 2011) shows the iGeneration spending almost all of their waking hours on media and technology prompting Rosen (2011) to suggest that education needs to be 'rewired' to cater for them.

2.3.1 Challenges Faced by the iGeneration

Results from extensive research conducted by Kaiser Family Foundation (2010), Pew Internet & American Life Project and Rosen (2011) show similar findings, which include children and teens spending nearly all their waking hours using media and technology. It must be noted that the list of media used include watching TV, listening to music, using social network sites and playing video games. The Kaiser Family Foundation collected comprehensive data on the amount and nature of different media use consumed from 8 to 18 year olds in 1999, 2004 and 2010. Key findings show an increase from an average of six and a half hours a day in 2004 to eight and a half hours a day in 2010. The use of every type of media has increased over the past 10 years except reading, which actually decreased. This transformation is aided by the revolution of mobile and online technology, increasing the opportunity for teens and tweens to consume media at every waking moment. One not so startling finding from this study showed almost half of the heavy users of media (usually consuming more than 16 hours on a typical day) getting fair or poor grades (mostly C's or lower). These children also indicate they are often bored or unhappy or sad. In a national survey to view teachers' perceptions on the use of entertainment media on their students' performance (Common Sense Research Study, 2012), 71% felt media use has hurt students' attention span, 58% say it has affected their students' writing skills and 48% think students neglect doing their homework due to time spent on media.

A study conducted by the Organisation for Economic Co-operation and Development (OECD) on OECD countries like United States, Canada, Australia, Japan, South Korea and European countries, students showed low interest in science and technology among secondary school students (OECD, 2007; Sjøberg and Schreiner 2005a). In another large international study, the Relevance of Science Education (ROSE) survey, found a similar pattern, with students from industrialised countries, such as Denmark and Norway, scoring lower on interest in science education (Sjøberg and Schreiner 2005b). In an analysis of the ROSE data, Sjøberg and Schreiner (2005b) found a strong correlation (−0.85) between an aggregate score for interest in science and the state of development of the country as measured by the United Nations Development Index. Hence, there is little wonder when scores from international tests such as the Programme for International Student Assessment (PISA) show students from the United States performing poorly in the 2010 assessment.

According to Osborne, Simon and Collins, (2003), the gradual decline in interest towards science over the last 20 to 30 years is cause for concern to policymakers as the scientific literacy of their population will affect the country's science and technology, which inadvertently will affect the nation's economy. On the same vein, Bill Gates (2005) highlighted that "training the workforce of tomorrow with the high schools of today is like trying to teach kids about today's computers on a 50-year-old mainframe. It's the wrong tool for the times."

It is evident there is a growing discrepancy between current educational outcomes and the skills set needed to succeed in our increasingly complex world that is highly dependent on technology. As learning skills today go beyond what student needs to learn but how and when they learn, it is imperative to understand the role of digital media in the lives of these students in order for educators to proactively find ways using media to reach out, engage and educate the iGeneration. Even so, conflicting views occur between teachers and students in America with only 46% of teachers saying their homework require technology while 94% of students say they use technology to do homework. To bridge this gap, teachers must keep up with technology and the learning styles of students to meet the requirements of the 21st Century education.

2.3.2 Chemistry Content Among Upper Primary Students in Malaysia

Chemistry is commonly known as the central of science. It is one of the most important branches of science that enables learners to understand the phenomena that occurs around them. It is normally taught as a separate subject in secondary or high school in many countries but in Malaysia, Chemistry is integrated with Physics and Biology and taught as general science to the lower secondary students. Chemistry learning will only be offered as an elective subject in upper secondary level.

At the lower secondary level, students are introduced to general Chemistry when learning Science. The Chemistry content becomes more detailed and in-depth when Chemistry is taught again in upper secondary level. For example, students in Form One will learn about the properties of solid, liquid and gas when they learn about ‘Matter’. In upper secondary level, they will understand more about the characteristics of the particles in solid, liquid and gas as they connect the macroscopic with microscopic and symbolic when they learn about matter again.

Based on the spiral curriculum theory, the learning of Chemistry takes on an even more general approach in upper primary level. For example, while students in the upper secondary explain ‘Matter’ using the particulate and kinetic theory, students in lower secondary learn about the characteristics of matter such as mass, volume, shape, density in each state. Students in upper primary on the hand are taught basic concepts like matter exists in three states. They are also taught to identify and give simple examples of these three states of matter, while changes in states of matter are limited to using water as an example. In other words, the learning of Chemistry at this level is very minimal and general. Other areas of Chemistry learning covered include basic knowledge of acid, alkaline and neutral substances, understanding the characteristics of spoilt food, factors that cause food spoilage and types of food preservation. A special section is also included on basic waste management and the effects of improper waste disposal.

At the primary level, students are not exposed to basic chemical symbols and most physical separation techniques taught in Chemistry. They have not also been taught about basic chemical bonding as these topics will only be taught at the secondary level.

2.3.3 Challenges in Learning Chemistry

It is a known fact that Chemistry curricula are filled with complex and abstract concepts needed for further learning in both chemistry and other sciences (Taber, 2002). These abstract concepts are important because further chemistry/science concepts or theories cannot be easily understood if these underpinning concepts are not sufficiently grasped by the student (Zoller, 1990; Nakhleh, 1992; Ayas & Demirbaş, 1997; Coll & Treagust, 2001a; Nicoll, 2001). The abstract nature of chemistry along with other content learning difficulties (e.g. the mathematical nature of much chemistry) means that chemistry classes require a high-level skill set (Fensham, 1988; Zoller, 1990; Taber, 2002).

Numerous studies have been conducted to investigate the reasons why students find learning Chemistry difficult. A number of studies cite language as the issue (Johnstone & Cassels, 1978; Cassels & Johnstone, 1983; Byrne, Johnstone & Pope, 1994). For many students, the subject itself is perceived to be difficult, abstract, complex and requiring special intellectual talents to understand (Ben-Zvi, Eylon & Silberstein, 1987; Gabel, 1999; Johnstone, 1991; Nakhleh, 1992). There is also a perception that chemistry is boring and relies on making sense of the "invisible and untouchable" (Aikenhead, 2003; Kozma & Russel, 1997).

One of the essential characteristics of chemistry is the constant need to connect between the macroscopic and microscopic levels of thought, and it is this aspect of chemistry learning that represents a significant challenge to novices (Bradley & Brand, 1985). Topics that students found difficult in Chemistry included the mole, chemical formulae and equations, and, in organic chemistry, condensations and hydrolysis. Reports by Johnstone (1974) found that these areas of problem usually persisted well into university education. Although rote learning often helps students overcome their lack of comprehension, real understanding demands the bringing together of conceptual understanding in a meaningful way. Thus, while students show some evidence of learning and understanding in examination papers, researchers find evidence of misconceptions at various levels in certain areas of basic chemistry, which are still not understood even at degree-level (Johnstone, 1984; Bodner, 1991). In other words, what is taught is not always what is learned.

The perception that Chemistry is a difficult subject often repels learners from continuing with studies in Chemistry. In view of the hindrances that learners perceive in learning Chemistry, it is common knowledge that the interest towards studying science in general and chemistry in particular has decreased the world over (Childs & Sheehan, 2009; Farhana & Zainun, 2013; Johnstone, 2000; Osborne & Collins, 2000).

In Malaysia, the Ministry of Science, Technology and Innovation (MOSTI, 2008) revealed that only 44.9% of Malaysians are interested in new science inventions and discoveries compared to 87.0% of Americans and 78.0% of Europeans. In a more recent study, Martin, Mullis, Foy and Stanco (2012) discovered that only 55% of Malaysian students had limited prior knowledge in science.

In recent years, the ability of Malaysian students compared to students of other nations, in the cognitive domain (knowledge, application and reasoning) is below the TIMSS minimum score. For the knowledge attainment component, majority of the Malaysian students achieve the average benchmark score (n=457). While only 3 percent of Malaysia students are able to demonstrate deep conceptual understanding of certain complex and abstract concepts. Ability to apply scientific knowledge effectively and meaningfully requires deep reasoning. It was found that students lack the skills of making generalizations and constructing hypothesis.

With respect to science education, many educators have indicated that teaching students to apply scientific knowledge so that thinking and problem solving skills can be nurtured and cultivated should be a significant goal of science instruction (Chiappetta & Russell, 1982; Zeidler, Lederman, & Taylor, 1992; Zohar & Tamir, 1993). Thus, science educators must continually strive to create a conducive learning environment that enhances critical thinking and problem solving skills.

2.4 Importance of Attitude Towards Chemistry- Motivation

Educational psychologists have long been conducting studies to analyse how learning and achievement are influenced by attitudes and motivation, which are connected with individual and situational interest (Krapp, 1999). Numerous studies have supported the fact that interests were the most important motivational factors in learning and development (Dewey, 1913; Thorndike, 1935; Krapp, Hidi, & Renninger, 1992). According to Garner (1992) and Alexander and Jetton (1996), interest has been found to determine in part what we choose to learn, and how well we learn this information. Social influences may play an important role in stimulating interest and this includes interaction with friends (peers) and teachers that provide guidance and encouragement. Interest can manifest itself in several ways, including being alert, focused, attentive, excited, actively engaged, responsive, and learning more than one would otherwise learn. Interest affects the use of specific learning strategies, our emotional engagement and how we allocate our attention (Hidi 1990; Schraw, Bruning & Svoboda, 1995). Kpolovie, Joe and Okoto (2014) discovered that having interest in learning leads towards positive attitudes in school, like academic achievement, are important outcomes of science education in secondary school. The development of students' positive attitudes towards science is one of the major responsibilities of every science teacher. Unfortunately, research has revealed that much of what goes on in science classrooms is not particularly attractive to students across all ages (Stark & Gray, 1999).

It is important to develop students' positive attitudes to science lessons in school due to two main reasons. Research has confirmed that attitudes are linked with academic achievement. For example, Weinburgh's (1995) meta-analysis of research concluded that the correlation between attitude toward science and achievement is 0.50 for boys and 0.55 for girls, indicating that attitude can account for 25–30% of the variance in achievement.

Using a posttest-only control group design, Freedman (1997) found that the correlation between attitude toward science and achievement was 0.41 in the treatment group. Salta and Tzougraki (2004) reported that the correlation between high school students' achievement in chemistry and their attitudes toward chemistry ranged from 0.24 to 0.41. Bennett, Green, Rollnick and White (2001) also discovered that undergraduate students who had a less positive attitude to chemistry almost invariably obtained lower examination marks.

Another reason why it is important to develop students' positive attitudes toward science lessons taught in school is that attitudes predict behaviours and inevitably interest (Glasman & Albarracín, 2006; Kelly 1988). For example, Kelly (1988) found that British students' liking for a particular science subject was a good predictor of their actual choice of physics, chemistry, or biology in schools. In another study presented by Hofstein and Mamlok-Naaman (2011), the most effective factor contributing to students' motivation and decision to study science was their interest in the subject. In addition, it was discovered that the use of technology had a positive impact towards the attitude and motivation in learning Chemistry (Berg, 2005; Cai, Wang & Chiang, 2014; Di Serio, Ibanez, & Kloos, 2013).

In Malaysia, substantial investment have been spent on technology, but the use of technology in classrooms remain limited with Zakaria and Iksan (2007) identifying two pedagogical limitations as the major shortcomings in traditional secondary education: lecture-based instruction and teacher-centred instruction. Lecture-based instruction emphasized the passive and superficial attainment of knowledge (Bransford, Brown, & Cocking, 2000). In such an environment, students become passive recipients of knowledge and resort to rote learning. The majority of work involved "teacher-talk" using either a lecture technique or a simple question and answer that demand basic recall of knowledge from the learners. Lecture based instruction dominates classroom activity with the teacher delivering well over 80% of the talk in most classrooms. These pedagogical limitations attribute for much of the disinterest in learning Chemistry as it fails to stimulate student motivation, enthusiasm and confidence (Weimer, 2002). Over the past two decades, there is a growing body that recognizes the advantages of student-centred instructional technologies, allowing active learning among students (American Association for the Advancement of Science, 1989; Bransford, Brown, & Cocking, 2000; Handelsman, 2004, Handelsman, Miller, & Pfund, 2007; National Research Council, 1999, 2007; Project Kaleidoscope, 2006) This approach leads to increased interest and motivation, thus promoting meaningful learning, problem solving and critical thinking, which increased learning outcomes (Freeman et al., 2007; Knight & Wood, 2005; Marbach-Ad, Seal, & Sokolove, 2001; Preszler et al., 2007; Prince, 2004; Udovic et al., 2002).

2.5 Situated Learning - The Theories Behind Digital Game Based Learning

The definition of learning has been a topic of debate by educational psychologist and but many agree that learning is a process of acquiring new or modifying existing knowledge, behaviours, skills, values or expertise and leads to a change in behaviour (Dewey, 1944; Lawton, Saunders & Muhs, 1980; Piaget, 1971; Thorndike, 1935; Vygotsky, 1978). In the past, rote learning had been the main advocate for learning. Although it helps the learner to recall basic facts quickly, Dewey (1944) firmly believed that rote learning should not be the primary focus of education. In today's world, the need to memorize facts is quickly losing ground as information is no longer restricted to the pages of a book and assessable only from bookshelves, but available instantly at the touch of a screen. Moreover studies have shown that learners are able to recall information and apply the knowledge learnt better when learning becomes meaningful. According to Ausubel as cited by Lawton, Saunders and Muhs (1980), meaningful learning encourages learners to build their cognitive skills to evaluate, analyse, compare and remember facts they obtain. Hence in order to achieve meaningful learning, active participation is needed to constantly construct and integrate new knowledge with prior knowledge. McLeod (2008) mentions that according to Jerome Bruner students discover and construct new ideas when they participate actively in the learning process. The features of digital games allow both implicit and explicit learning to occur through all three modes of representation described by Bruner as students intuitively navigate through the game. Another educational psychologist who supports the idea of active participation to constantly construct knowledge is Jean Piaget. However, according to Papalia, Olds, and Feldman, (2011), Piaget posits that development precedes learning and learning only happens when a child has reached the requisite stage. In addition, Piaget mentions that each child constructs knowledge independently without the need for social interaction or guided participation.

In contrast, Vygotsky believes that 'no man is an island' and active participation within the social community helps in the construction of knowledge in a child. In Vygotsky's theory (as written by McLeod, 2014), social interaction is the core of a child's cognitive development whereby he believes that learning precedes development. He further argues that the cognitive development of a child results from the guidance of a more knowledgeable person, be it an adult or peer. In addition, Vygotsky believed that true education is not limited to learning specific knowledge or skills but the development of the child's learning abilities to think clearly and creatively, plan and implement their plans and articulate their understanding in a variety of ways. The key to achieving this ability is by using a variety of psychological tools to extend our mental abilities. These tools include signs, symbols, maps, plans, numbers, musical notation, charts, models, pictures and most importantly language, which are common tools in most digital games today. The use of these tools leads to the development of new psychological abilities and in turn the blooming of a child's personality.

Vygotsky also believed the role of a teacher in education is crucial, not only in developing the child's learning ability but also reaching the child's zone of proximal development (ZPD). Vygotsky describes ZPD as the distance between one's actual development achieved by oneself and one's potential future development through the assistance of the expert or more skillful peers. In his last lecture, *Play and Its Role in the Mental Development of the Child,* Vygotsky (1967) emphasized the importance of play during the formative years whereby play also creates the ZPD of the child.

The benefit of learning during playtime is maximized when facilitated by a teacher. Teacher intervention can come in many forms such as assistance in problem solving, redirecting inappropriate behaviour, posing questions to stimulate thinking and creating interest and motivation to play, and is necessary to provide the scaffolding to achieve the child's ZPD.

The theories put forth by Vygotsky is supported by Squire, Barnett, Grant, and Higginbotham (2004) in their study, whereby students who played a computer game in physics called "Supercharged" were able to conceptualize and recall experiences to problem solve better than students from the control group who relied mainly on their ability to memorize information. These initial findings suggest that digital games afford instructional tools and context to represent concepts required to elicit thinking and promote creativity in players. In addition, the study acknowledges the need for teachers to provide guidance and scaffolding for students to achieve their ZPD. In this instance, teachers were needed to monitor the learning outcomes of players, provide structure for more focused play and learning in the form of prompting deeper reflection on the game and encouraging students to interpret the events happening. More recent studies conducted by Beckett (2013) and Loukomies et al. (2013) also supports the fact that teachers still play a crucial role in a child's educational development. Finally, findings from the study conducted by the researcher also supports Vygotsky's cognitive development theory as results from this study revealed that students who had teacher intervention showed higher attainment of Chemistry learning from qualitative results compared to the pilot study. These findings are discussed under Findings and Discussion, Chapter 5.

A more recent learning theory that is related to Vygotsky's idea of learning through social development is the Situated Learning Theory (Lave & Wenger, 1991). This theory posits that learning is unintentional and situated within an authentic, context and culture. Proponents of situated learning believe that the learning style of the iGeneration leans towards acquiring knowledge unintentionally through the experiences they encounter from the games played. Randy Pausch (2007) termed this learning method as "head fake" in his last lecture in Carnegie Mellon University. The researcher concurs with Pausch as she observed how implicit learning of Chemistry occurs among the students during game-play. In other words, students thought they were playing a game and were unaware that they were actually learning Chemistry. These implicit learning were later manifested into explicit learning of Chemistry with the aid of scaffolds, which included teachers as facilitators.

These findings support Gee's (2003) argument that situated learning provides deep learning, which involves activity and experience. He extrapolates that when a learner treats knowledge first and foremost as activity, the facts and information which normally requires memorization and rote learning will follow if the learner becomes immersed in the activities and experiences which use these facts within a coherent knowledge domain (Gee, 2004; Shaffer, 2004). It is crucial to note that for deep learning to occur, there must be a merger between allowing the learner to engage in the domain's activity as well as providing sufficient scaffolding to ensure learning becomes meaningful (Gee, 2004; Pausch, 2007; Squire, Barnett, Grant, & Higginbotham, 2004).

2.6 The Role of Play in Learning

It is an undeniable fact that children learn best in an environment that allows them to explore, discover and play (Dewey, 1944; Froebel, 1887; Fromberg & Gullo, 1992; Frost, 1992; Hirsh-Pasek, Golinkoff, & Eyer, 2003: Hirsh-Pasek et al., 2009; Huizinga, 1955; Piaget, 1971; Vygotsky, 1978). Early theorist such as Rousseau, Froebel and Dewey have been advocates of play based learning in early childhood and they believe that children learn naturally from play. Children are believed to be co-constructors of their learning and active participants in shaping their learning process.

Play is considered an integral part of a child's development with Frost (1992) concurring that play allows for the development of imagination, intelligence, language, social skills and perceptual-motor abilities in infants and young children. Fromberg and Gullo (1992) further concludes that play has been proven to develop the creativity, imagination, thinking skills as well as the social and language competency of a child.

According to Vygotsky (1978), the greatest achievements attained from a child's play may become her basic level of real-life action. When children play, their state of mind and body language changes to a state that allows conducive learning to occur as they become engaged, participative and interested. Their minds are activated and challenged and they are willing to try out new ideas, experiment with their surroundings, test concepts, explore and take risk without the fear of failure. Besides that, the lack of pressure during playful learning allows the child to try again and again, explore new ideas and let their imaginations take charge, leading to significant development in a child's intellectual, social, emotional and physical state.

It is proven that play fosters engagement, stimulate the sensory organs and allow the learner to build content knowledge, creative thinking, problem solving skills as well as enhance memory retention (Christie & Rosko, 2015; Cooper et al., 2009; Dickinson & Tabors, 2001; Ginsburg, Lee, & Boyd, 2008; Weiland & Yoshikawa, 2013). Through play, children learn to communicate, tolerate each other, build friendship and have empathy as they take another's perspective into consideration, thus allowing their social skills to develop. (Project Zero & Reggio Children, 2001; Mraz, Porcelli, & Tyler, 2016). When children play, they engage in activities that require them to listen, pay attention, control their impulses and self-regulate as they learn to follow rules. These tasks help children to develop emotional competencies (Berk, Mann, & Ogan, 2006; Elias & Berk, 2002).

In our current generation, it is noted that children are no longer interested in the didactic method of instructional technology and it is opined the education system need to move on to catch up with the interest and motivation of students to learn. In recent years, the exponential growth of digital technology has caused children to form such a close bond towards playing digital games.

2.7 Digital Game Based Learning in Education

With the advancement in digital technologies, it is only natural that educational researches have shifted towards the use of digital games in education with DGBL research championing the cause to meet the needs of our millennial generation. In their academic textbook on game design, Rules of Play: Game Design Fundamentals, Salen and Zimmerman (2004) state, "the goal of successful game design is the creation of meaningful play". Meaningful play is not obligatory or forced and comes as a result of full interest and attention from the players. The use of digital games for educational purposes have been around for some time (Levine, 2006) and in recent times they have attracted increasing interest among educators due to the exponential rise of digital gaming in popular culture, and claims regarding the potential of games for facilitating engagement, motivation and student-centred learning. Such claims have led to the coinage of the term “serious games”: a term used to describe games that do not have entertainment, enjoyment or fun as the primary purpose (Michael & Chen, 2005). These games are used in teaching and training in various field like the military, healthcare, engineering, city planning, corporate, media, advertising and education (Laamarti, Eid & El Saddik, 2014).

It is undeniable that digital games have become pervasive among all teens with Pew Research Center (2015) citing 72% of all teens in the United States playing videogames. Gaming has become an important activity, through which friendships are formed and maintained, and findings like these are not novel as Entertainment Software Association, (2006) discovered 69% of American households play computer and videogames a decade ago. Constructivist educators realize that the only way to catch hold of the iGeneration interests is through the media they spend most of their time on and the advancement of digital games in education led to Prensky (2007) using the term Digital Game Based Learning (DGBL) in his book with the same title. As serious game encompasses many other fields besides education, DGBL is considered a section of serious games, which incorporates education and learning as the main purpose. Proponents of DGBL have published an array of essays, books and articles to support the use of such games in education. Among those published are Digital Game-Based Learning by Marc Prensky (2001b), What Video Games Have to Teach US about Learning and Literacy (2003), Simulations and the Future of Learning: An innovative (and perhaps revolutionary) Approach to e-Learning (2004), Everything Bad Is Good for You: How Today's Popular Culture is Actually Making Us Smarter by Steve Johnson (2005) and the most recent book by Prensky (2006) entitled "Don't Bother Me, Mom, I'm Learning!" and How Computer and Video Games Are Preparing Your Kids for 21st Century Success and How You Can Help!. From the findings of these researchers, one common agreement is that the iGeneration have become disengaged with traditional instruction and require multiple streams of information, prefer frequent and quick interactions as they have exceptional visual literacy skills (Van Eck, 2006). Another factor that supports the use of DGBL is increased popularity on digital games especially among the iGeneration, where the market revenue has grown from USD $10 billion in 2004 to a projection of over $100 billion by end 2017 (James Batchelor, 31 Jan, 2018).

With the rising interest of using digital games in education, numerous research papers providing theoretical and empirical evidence have been published. Among the claims to support DGBL are digital games are built on sound learning principles (Dickey, 2005; Gee, 2009; Groff, Howell & Cramer, 2010; Ke, 2009; Klopfer, Osterweil & Salen, 2009), digital games provide personalized learning opportunities (Ash, 2011; de Jong & van Joolingen, 1998; Ketelhut, Dede, Clarke & Nelson, 2006; Kickmeier-Rust, Hockemeyer, Albert & Augustin, 2008; Klopfer, Osterweil, & Salen, 2009; O'Neil, Wainess, & Baker, 2005), digital games provide more engagement for the learner (Barab, Arici, & Jackson, 2005; Csikszentmihalyi, 1990; Gee, 2003, 2007; Groff, Howell, & Cramer, 2010; Prensky, 2001b; Rupp, Gushta, Mislevy & Shaffer, 2010), games teach 21st century skills (Gee & Shaffer, 2010; Johnson et al., 2011; Rupp et al., 2010; Shaffer, 2004; Squire, 2006) and digital games provide an environment for authentic and relevant assessment (Baker & Yacef, 2009; Behrens, Frezzo, Mislevy, Kroopnick & Wise, 2007; Koenig, Lee, Iseli, & Wainess, 2010; Shaffer, 2009).

In Malaysia, research on DGBL in the field of mathematics among primary school learners have shown to yield positive results on students' motivation and achievement (Hussain, Tan, & Idris, 2014), while another study conducted on secondary students showed an increase in students' motivation to learn history (Matzin & Wong, 2013).

Nevertheless, researchers realize that not all games are good for all learners and for all learning outcomes (Van Eck, 2006). Van Eck further proposes that more research should be conducted to explain why DGBL is engaging and effective. Practical guidance for how, with whom, and under what conditions games can be integrated into the learning process to maximize learning potential must also be investigated. Although there is a growing body of literature on the learning theories, models and principles that are incorporated into DGBL, many DGBL proponents are concerned about the dangers of academizing or sucking the fun out of games (Prensky, 2011). This concern is due to the fact that many edutainment software were designed and produced by academicians who had little or no understanding of the art, science and culture of game design over the last decade. This resulted in games that were educationally sound as learning tools but lack appeal as games. But at the same time, if games were to be solely designed by game designers with no inclination of learning theories, models and principles, it may prove to be a disaster. In this catch 22 situation, educators must realize that developing a game is a resource draining activity that requires a multi-disciplinary team to work on the game design as the game produced must not only provide the desired learning outcomes but also must catch the interest and motivation of players. Moreover, teachers who use the game must learn to master the game so that they can provide the necessary scaffolding to assist students during game play. In fact, some of the issues highlighted by Osman and Bakar (2011) were teacher's competency, game design quality and aligning the game with curriculum.

2.7.1 Digital Role Play Games (DRPG) in Chemistry Learning

The history of role-playing games in the form of pen and paper date back in the 1970's (Mason, 2004) with Dungeons and Dragons. Since then, they have evolved into a wide variety of styles and media, including digital with a single player to thousands of players (Hitchens & Drachen, 2008). Even back in those days, live role-play games were used to improve aspects of teaching and learning through students' engagement and active learning. Through live role-play games, students learn to problem-solve, empathize and learn from playing certain role. As digital games gradually consume a significant amount of the iGeneration's attention and time, educators scramble to find ways and means to converge pedagogical benefits of role-play games with educational technology and digital games. Randi and de Carvalho (2013) found quantitative support to show DRPG provided active learning and memory retention as well as being effective compared to formal lectures among varsity students. In another study conducted by Tsai, Yu and Hsiao (2012) on sixth grade students using an educational online game called Super Delivery. Results from the study found that students' learning motivation, learning ability and playing skill were affected by their motivation to play, prior knowledge and online game experience, which in turn affected the learning effectiveness and knowledge attainment. Hsieh and Huang (2014) found using DRPG increases students' participation rate compared to non-gamified course design over a 3-year period. In addition, an informal query showed gamification design courses were more popular as students were more engaged and motivated to participate voluntarily in the activities of the course.

Interest and motivation are one of the key factors that ensure the success of learning and as mentioned in Chapter 1 under Problem Statement, one of the reason students in Malaysia show disinterest to study Chemistry is due to the lack of interest and motivation to study the subject (Farhana & Zainun, 2013; Muzammila, Johari & Murad, 2014; Woldeamanuel, Atagana & Engida, 2014). Research shows that when students are motivated, they will engage more easily with problems (Resnick, 1987), even difficult ones and have meaningful learning. This form of digital game has been proven to provide immersive environments through its fun and interactive media, engaging learners actively and arousing their motivation to learn. Thus, facilitating the meaningful learning through a realm of discovery learning (Barko & Sadler 2013; Holzinger, Kickmeier-Rust, & Albert, 2008; Lassiter et al. 2001; Lombard & Ditton 1997).

When DRPG is applied in Chemistry education, it allows the learner to manipulate a playable character (PC) while interacting with non-player characters (NPC) to obtain useful and vital information to accomplish quests and missions. This means the learner actively constructs new Chemistry knowledge as he explores and actively participates in the game. This method of learning can stimulate reflective thinking and trigger higher levels of motivation unlike traditional learning, which is passive, didactic and lacks exploratory means to acquire knowledge (Avargil et al., 2012; Barab et al., 2009; Gee, 2003; Mitchell & Savill-Smith, 2004). The benefits of meaningful learning through the active participation of learners in immersive environments using DRPG in Chemistry is supported Chen, Wong and Wang (2014) who developed a 3D RPG for students to learn chemical formulas. In the study, the researchers observed that although prior knowledge were essential to obtain higher levels of self-efficacy, students with lower levels of prior knowledge were actually more motivated by this method of learning. Besides that, the presence of scaffolds in the form of worked-examples provided guidance to enhance comprehension, thus allowing students to employ active learning strategies to solve problems and achieve their ZPD. In must be noted that the presence of play in an interactive media allowed students to explore and learn Chemistry effectively and meaningfully, especially when play reduces the stress of learning and removes the boredom that entails from passive learning.

Despite DGBL and DRPG having caught the attention of many progressive educators, it does not mean that society is ready to massively adopt them in the educational system (Torrente, Moreno-Ger, Martínez-Ortiz, & Fernández-Manjón, 2009). The researcher herself has personally found this resistance existed during her journey to explore its potential in education. This reluctance could stem from the fact that many educators in Malaysia do not associate digital games as part of play based learning nor do they view playing digital games to be associated with the learning curriculum.

2.8 Past Methodologies using DRPG in Education

Digital role-play game (DRPG) fall under the broad umbrella of digital game based learning (DGBL) and although past methodologies of DGBL studies are numerous and varied (Ash, 2011; Barab, Arici, & Jackson, 2005; de Jong & van Joolingen, 1998; Dickey, 2005; Gee, 2009; Gee & Shaffer, 2010; Groff, Howell, & Cramer, 2010; Johnson et al., 2011; Ke, 2009; Kickmeier-Rust, Hockemeyer, Albert, & Augustin, 2008; Klopfer, Osterweil, & Salen, 2009; O'Neil, Wainess, & Baker, 2005), there is a smaller number of past methodologies involving the use of DRPG in education.

In a quantitative study conducted by Randi and de Carvalho (2013) involving 230 first year undergraduate medical students from two public universities, RPG was used as a methodological approach for teaching cellular biology. These students an RPG based class or a lecture based class. Pre and post RPG questionnaires were compared to scores in regular exams and findings show RPG classes are quantitatively as effective as formal lectures and are better accepted than formal lectures. It was also concluded that RPG may well serve as an educational tool as it allows students to participate in active learning and retain the attained knowledge more efficiently.

In another study conducted by Chen, Wong and Wang (2014) that focuses on using DRPG in teaching Chemistry with the learning of Chemical Formula, a quasi-experimental design was used to investigate the effects of the exploratory strategy and level of prior knowledge on 108 lower secondary school students. The participants were identified as the high prior-knowledge group or the low prior knowledge group based on the mean score of their chemistry score in the previous semester. Two types of exploratory learning strategies were employed, one with worked example and the other without worked example. The independent variables were the type of exploratory learning and prior knowledge; while the dependent variables were learning performance (knowledge comprehension and knowledge application) and motivation toward science learning. A 3D RPG game, the Alchemist's Fort, which was developed by the researchers using the 5E instructional model was used as the learning framework and all participants in the study have acquired sufficient prior knowledge and understanding of fundamental chemical concepts before playing the game. All participants took the achievement test and motivation questionnaire immediately after the three weeks research duration. The data was analysed using Multivariate Analysis of Variance (MANOVA) tests.

In contrast, Tsai, Yu and Hsiao (2012) conducted a case study on eight sixth grade students using an online digital role-play game developed by the researchers themselves called Super Delivery. Four students with high level of prior knowledge and four students with low levels of prior knowledge were chosen. Prior level of knowledge was determined based on last semester's mathematics and science grade. The study period spread over a length of six weeks with students playing one session per week, with each session lasting 40 minutes. During the intervention period, all participants were asked to sit in a computer lab with no face-to-face interaction. However, students were allowed to communicate and help each other only in the game environment. They were also asked to think aloud during game-play for researchers to document observations. Researchers acted as observers as they sat silently behind the participants and recorded the participants verbal and nonverbal behaviour. After the intervention period, the performance test was distributed to participants. To evaluate the participants' effectiveness of knowledge attainment, a paper based performance test with 5 multiple-choice (MC) items and 5 constructed-response (CR) items were composed. Finally, each participant was interviewed individually and was asked questions regarding their learning perceptions and electricity knowledge. Data collection consisted of observations, think-aloud verbal protocols, game-playing records and semi-structured interviews. These multiple collection methods were triangulated and the quantitative data from the MC and RC were used as evidence to support the qualitative data. The most prominent finding from the study was that students' playing motivation negatively corresponded with their learning motivation. This in turn affected their learning effectiveness. The study noted that students with high playing motivation were only interested in scoring and winning, and avoided reading the learning content. A high prior knowledge helped students achieve high learning ability and produce a higher learning outcome. However, it must be noted that this study disallows face-to-face interaction among students. In addition, teachers only acted as mere observers and data collectors. Hence, the study did not look into how teachers can intervene and facilitate the learning of students along their ZPD.

From the past methodologies, it was found that the participants in all the research study were chosen from the same age cohort and are at the right cognitive developmental age to learn the knowledge presented. This theory of cognitive development precedes learning was theorized by Piaget, as presented by Papalia, Olds, and Feldman, (2011). Moreover, in one of the past methodologies that had a negative correlation between playing motivation and learning outcome, participants were not allowed to have face-to-face interaction during the intervention period. This method of intervention prescribes to Piaget's theory that each child constructs knowledge independently without the need for social interaction or guided participation. Finally, the researcher also discovered that the DRPG used for all the past methodologies were developed by the researcher and were only used during the research project. There was no evidence to show these games were further developed for the commercial market or incorporated into the education curriculum after the research period ended.

2.9 The Need to have Commercialized Educational DRPG

According to Van Eck (2015), after over a decade of documented proofs, the proponents of DGBL learning have finally convinced the public that digital games can indeed play a positive role in education. But one other challenge remains, and that is designing effective educational digital games that provide immersive environments to support powerful learning theories like meaningful learning through exploratory and situated learning, without sucking the fun out of playing. Commercial, non-educational DRPG are known to produce simulating, immersive games that can create a state of 'flow' like World of Warcraft that has drawn over 5.6 million players in August 2015 (Frank, 2016). A state of 'flow' (Csikszentmihalyi, 1990) is characterized by the deep and full involvement and enjoyment in the activity that nothing else seems to matter. The high quality in production, which includes good artwork, animation, sound and game design that provides diversity in experience all plays an instrumental factor in creating the 'flow'. Furthermore, a national survey conducted in the United States (Takeuchi, & Vaala, 2014) reported 80% of teachers who integrated digital games found it difficult to find curriculum-aligned games in the market that would interest students.

Nevertheless, educators face problems in creating the ‘flow’ and maintaining students’ motivation as students find DRPG designed by educators uninteresting and monotonous, to the point of being labeled boring. Moreover, these games are often limited to be used only during the research period, as students prefer to spend their time on commercial DRPG games that are more appealing. The ability to produce a well-designed DRPG requires a balance between educators to provide the content with powerful learning theories and game programmers to provide the flow, which captures the interest and motivation of players. However, this usually means a substantial amount of capital is required in the production of such games. This limitation of resources has led to the failure of many DRPG games that are normally not used beyond their research period.

In view of this, the researcher aims to explore the possibility of a DRPG that claims to have successfully merge both design and educational content. This DRPG is known as ChemCaper and it is recognized as the first Chemistry DRPG to be launched in the commercial market in 2016 (PRNewswire, 2016).

2.10 Chapter Summary

After over a decade of documented proofs, researchers acknowledge the need to use DGBL as an educational tool to bridge the gap between the skill sets needed for the 21st century learner to succeed in the future and the learning style of the iGeneration. However, the challenge that educators face is providing digital games that can merge both powerful learning theories and fantastic game design to capture the interest and motivation of students to play beyond the research period. This gives rise to the need to explore if ChemCaper, the first Chemistry DRPG to be launched in the commercial market can really reinvent the way to learn Chemistry for the iGeneration.

In addition, although much research has been conducted on the benefits of using DRPG in education but none have looked at the possibility of learning preceding the cognitive developmental of a child. In other words, would a child that does not have prior knowledge be able to learn using a DRPG.

The next chapter will provide a detailed description of the conceptualization of the study and the theoretical framework used while Chapter Four will be dedicated to the methodology used. This includes the sample population selection and the pilot study conducted in the study.

CHAPTER 3

CONCEPTUALIZATION OF THE STUDY

3.1 Introduction

Randy Pausch (2007), a computer science professor at Carnegie Mellon University, USA was diagnosed with pancreatic cancer and had a few more months to live before he gave a very inspiring lecture to his students about achieving their dreams no matter what cards were dealt to them. At the end of his lecture, he said, "I am sure you all thought this lecture was for you but actually it is not. It is for my three beautiful children". This is what you call a "head fake". A head fake is a term used by Randy to mean indirect learning when he described how his students had fun making video games without them realizing they were actually learning something difficult like computer programming.

In order to investigate if his legacy lives on in games like ChemCaper, it is imperative to address the issue of capturing the motivation of the iGeneration to learn Chemistry through a digital role-play game and as Randy mentioned in 'The last lecture'…. "millions of children having fun while learning something hard is cool" and what better way to do that but through something they love most, digital games.

3.2 Conceptual Framework

The conceptual framework of this study consists of ideas and concepts derived from previous studies that were identified as gaps to guide the development of the actual study. From all the past studies, prominent researchers in the field of psychology have all come to one common agreement and that is children develop physical, imaginative, language, social and cognitive skills as well as make sense of their world through play (Ginsburg, 2007; Piaget, 1951; Prensky, 2001b; Vygotsky, 1978). Hence, it is undeniable that play is an inevitable part of learning. In the actual study, play comes in the form of a DRPG.

Past research have also identified that in order for learning to occur, interest and motivation must come into the picture. From the literature review discussed in chapter two, when students are motivated, they will engage more easily with problems and have meaningful learning. It was also found that DRPG has been proven to provide immersive environments with challenges that are just difficult enough to engage learners effectively and motivate them to discovery and learn meaningfully.

However, the participants used in these past studies were required to have prior knowledge for the development and attainment of new knowledge (Chen, Wong & Wang, 2014; Randi & de Carvalho, 2013; Tsai, Yu & Hsiao, 2012). In other words, as discussed previously in literature review, the participants in these studies were required to be of the right cognitive developmental age to participate as posited by Piaget. To explore the reinvention of Chemistry learning, the researcher has leaned on Vygotsky's theory that learning can precede cognitive development stage. This justifies the use of primary students who have no prior Chemistry knowledge as the sample population. The identification of the gap for the actual study is as illustrated in Table 3.1.

In addition, the researcher has also identified another gap where learning can occur based on skills and not age. Although, the common practice in education across the globe is to group students based on age, there have been proponents that education should be based on skills and not age. However, there has been no empirical data gathered thus far of students being grouped together to learn Chemistry, especially using DRPG and this study might just contribute to the Brookings Institution, a nonprofit public policy organization based in Washington, DC that is currently researching on the idea of education being skills based, especially in the 21st century. In addition, the researcher also discovered in the pilot study that the absence of a teacher as facilitator (Tsai, Yu & Hsiao, 2012) showed that students did not maximize their ZPD.

Table 3.1

Identifying the Research Gap from Past Research using DRPG in Education

Researchers	Title of Article	DRPG Developers	Participants (Age cohort)	Prior Knowledge Needed?	Findings: (i) Interest & Motivation (ii) Learning Outcomes
Chen, Wong & Wang, 2014	Effects of type of exploratory strategy and prior knowledge on middle school students' learning of chemical formulas from a 3D role-playing game	The researchers	108 eighth-grade students	Students divided into high prior knowledge and low prior knowledge	(i) Learners showed mild positive motivation regardless of high or low prior knowledge. (ii) High prior knowledge group outperformed the low prior knowledge group
Randi & de Carvalho, 2013	Learning Through Role-Playing Games: an Approach for Active Learning and Teaching.	The researchers	230 first year undergraduate medical students from two public universities	Expected to be knowledgeable as all the students had passed a very competitive admission process	(i) Not investigated (ii) 78.4% found RPG an effective tool for learning.
Tsai, Yu & Hsiao, 2012	Exploring the Factors Influencing Learning Effectiveness in Digital Game-based Learning	The researchers	Eight sixth grade students	Students divided equally into high prior knowledge and low prior knowledge	Students' high motivation playing negatively affected their learning effectiveness as students were distracted with scoring and winning and avoided reading the learning content.

IDENTIFICATION OF THE GAP

In past studies, researchers using DRPG have selected participants from the same age cohort or of the same cognitive development stage. In addition, the selected participants were required to have a certain amount of prior knowledge in the area of investigation, indicating that the DRPG used in the intervention can only be used for a selected target population. Besides that, the DRPGs used in these studies were developed by the researchers and are not available in the commercial market for the general public to play. Although, these DRPGs have sound educational and pedagogical content, there is no evidence that these DRPGs were used beyond the research period. In one study, students were not allowed to have face-to-face interaction with teachers acting as observers only (Tsai, Yu & Hsiao, 2012). Findings from that study indicated that students' achievement might have been compromised, as they did not receive scaffolding along their ZPD.

The present study intends to explore the reinvention of Chemistry learning by:

1. Investigating the motivation of the selected group of iGeneration students when they play ChemCaper, a DRPG available in the commercial market for public to play.
2. Evaluating the Chemistry knowledge attained by the selected group of iGeneration students that have no formal learning of Chemistry. In other words, no prior knowledge of the subject is needed. This also means the selected participants are considered to be below the age of cognitive development according to Piaget's theory.
3. Assessing if Chemistry knowledge can be attained based on skills and not age by allowing the selected iGeneration students across different ages to play the same game and interact with one another during the intervention period.
4. Investigating the importance of scaffolding for the selected iGeneration students.

3.2.1 The Assessment of ChemCaper, a selected DRPG

From literature review, educators realize there is a need to meet the learning styles of the iGeneration. With these kids spending up to eight and a half hours on various digital media daily (Kaiser Family Foundation, 2010), proponents of DGBL have provided both theoretical and empirical support on the use of DRPG in education. However, research also reported that many DRPG developed by academicians contain effective educational content but are unable to penetrate the commercial games market due to lack of appeal in game design and features to capture the interest of players.

The contemporary approach is to create a game genre with sound learning content that can provide the flow and immersion to keep players motivated to continue playing. As ChemCaper claim to be the first Chemistry DRPG with sound educational content launched in 2016 in the commercial games industry, the researcher felt impressed to investigate if this DRPG may actually fit this gap. The developers of this serious game attest to it 'reinventing Chemistry learning' as feasibility studies conducted by the developers show that children do actually learn from just playing games; be it implicit or explicit learning. In addition, this DRPG believes that learning can occur irrespective of age, just like how players of all ages play other non-educational DRPG available in the games industry.

From interviews conducted with the game developers, the researcher found that the main instructional designs for ChemCaper is Situated Learning as students are "situated" in a learning environment that allows them to participate actively in the activities of the game through the situations the players encounter when they assume the role of an avatar, accept quests and solve the problems faced by the avatar. The game design is found to contain attractive visuals and catchy phrases (Appendix A), with jokes inserted (Appendix B) when a player logs into game to set the right state of mind for the player. According to Hamari, Koivisto, and Sarsa (2014), playing digital games can increase learning. However, one key element to keep players engaged in a game is the context of the digital game. Further investigations conducted by Hamari et al. (2016) showed that constant developments of challenges in a digital game as player abilities grow could provide the immersion and engagement needed in learning. This is in line with Vygotsky's theory of zone of proximal development. Moreover, the many routine activities such as trace apparatus, craft potions and bond petticles besides fighting monsters and the 'Boss' to level up are believed to develop mastery of skills, which will in turn lead to both implicit and explicit learning in attaining the knowledge of Chemistry.

Therefore, this study aimed to investigate how the game can fulfill the learner's needs in capturing motivation besides providing effective learning content. Investigations into ChemCaper included looking at the non-linearity aspect of this DRPG, which is the most vital component in the game features and design. In addition, the reward system of ChemCaper works best with younger children as they look forward to rewards, thus fulfilling their satisfaction in playing the game. When players are rewarded based on performance and quest completion, it will spur them to find ways and means to solve the quest and generate discussion among peers and with teacher, thus creating interest in the game. Another factor in game design is to create challenges that are pleasantly difficult but fun, and tailored according to the skills of the player.

The need to understand how playing ChemCaper can elucidate the learning of Chemistry, whether implicit or explicit is another significant factor in this study. One such measure is to understand how learning occurs through the play of this game. Factors influencing this measure included game instructions, the mastery of the game due to its repetitive nature and the influence of peers (cooperation or competition) as well as teachers. Vygotsky states that scaffolding is vital to the cognitive development of a child. In fact, the role of teachers as facilitators has actually emerged from the findings of the pilot study and has been included under discussion of Findings in Chapter 5. The conceptual framework of this study allows for students of different ages, who have not been introduced to formal Chemistry learning the opportunity to engage with the game and with friends for one hour after school everyday during game-play. The influence of a scaffold along the ZPD was evaluated by the presence of teachers as the more knowledgeable other (MKO) and providence of an instructional guidebook midway through the two week period of study. During this time, understanding how students attain Chemistry knowledge was obtained through observations from the researcher and teachers involved. The observations collected from teachers included during school time and game time. Finally focus group interviews were conducted to understand how students construct their knowledge.

Another vital component of the study was to establish how much learning has occurred through students' self-discovery and mastery of the game as well as through cooperation, competition and collaboration with friends and teachers. Therefore, there was also a need to develop an interactive assessment to evaluate the Chemistry content learnt among the students of different ages after playing ChemCaper at the end of the research period. However, to ensure that learning has occurred from playing ChemCaper, a written assessment was administered to students at the end of the first week of game-play and again, at the end of the second week of game-play. The students were also be administered an interactive assessment after they have completed the two weeks of game-play. From these assessments and evaluations, the reinvention of Chemistry learning was explored to evaluate the potential of using ChemCaper, a DRPG as a tool to teach Chemistry knowledge to players that are considered too young to learn such a difficult subject in the mainstream school.

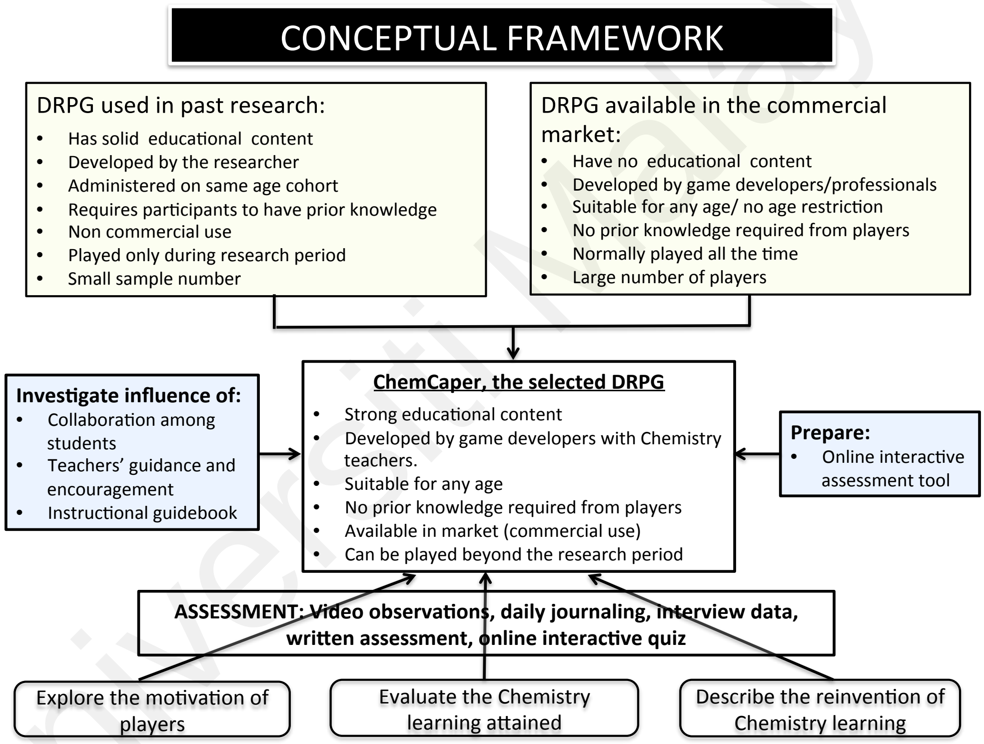


Figure 3.1: The conceptual framework for the present study

3.3 Theoretical Framework

"If you tell me I will listen. If you show me I will see. If you let me experience, I will learn." - Lao-Tzu

Children love to play and play is imminent in the development of many positive outcomes with learning being one of them. Play provides opportunities for children to develop their social, cognitive and emotional domains, which includes creativity, concentration, perseverance, memory skills, and problem solving skills among others (Elkind, 2008; Ginsburg, 2007; Hirsch-Pasek et al., 2009; Partnership for 21st Century Skills, 2009; Piaget, 1959; Prensky, 2001b; Saracho & Spodek, 2006; Vygotsky, 1978). Jean Piaget (1951) postulates that "play is the answer to how anything new comes about" increasing cognitive development while Bruner (1960) adds that children are active problem solvers, capable of solving "difficult subjects" as they are constantly constructing ideas and concepts from different types of stimulus, with interest in subject matter being the best stimulus for learning. His study leaned towards children learning intuitively through discovery learning when they have the interest and are motivated to learn. His concept of discovery learning implies that the learner plays an active role of building understanding and constructing new knowledge by discovering as the child masters skills that will lead to greater discovery and learning. Bruner's theory is strongly supported by Bicknell-Holmes and Hoffman (2000) who describes the three main attributes to discovery learning as exploring and problem solving to create, integrate, and generalize knowledge; have activities that interest students and allow them to determine that frequency and level of participation as well as activities that encourage integration of new knowledge into the learner's existing knowledge base. These attributes lead to meaningful learning and the researcher found these attributes to be present in the context of this study, which has been discussed under chapter five, findings and discussion.

Although many adults perceive digital games as being a waste of time and addictive for children, according to Gee (2003), a well-designed digital game is not only fun but can also have up to 36 implicit learning principles. Moreover, it is now widely accepted that digital games can be immersive, entertaining, motivating and fun while providing meaningful and valuable learning experience (Holzinger, Kickmeier-Rust, & Albert, 2008; Lassiter et al., 2001; Lombard & Ditton, 1997; Van Eck, 2006). Hence, the crux of a good DGBL is the ability to merge a good game design that engages the player, provide complete immersion and motivates the player while having sound theoretical learning theories (Ahn, 2008; Gillispie, Martin, & Parker, 2010; Van Eck, 2006, Papastergiou, 2009).

In this study, the foundations of Piaget and Bruner on play and discovery learning sits on the foundations of situated learning, a constructivist learning theory proposed by Lave and Wenger (1991). As Chemistry is considered a difficult subject even for older children to conceptualize, younger students can grasp the understanding of this abstract knowledge when they are placed in a situation or context where they become active learners through the activities they perform through the game. Gee (2003) argues that through game designs that promote situated learning, the activities at each different level in the game requires players to constantly plan and strategize as they actively discover how to solve problems faced in the game. All these activities, lead to meaningful learning to occur, albeit unintentionally within the game. Of course, all these can only happen more effectively if Vygotsky’s social learning is included in the activities. Role-play games are characterised with the element of storytelling with players taking the roles of an avatar in a fictional, often fantasy world.

With the exponential growth of the digital era, a rapid shift towards playing role-play games digitally has become a norm. The DRPG is a story driven game as research shows that the idea of story telling is a powerful element to capture interest, increase enthusiasm and aid understanding when delivering teaching, whether through explicit or implicit methods. The main idea of learning using a DRPG is to allow the child to actively explore, discover and make learning meaningful through a self-discovery game. As the iGeneration learners take to digital devices like fish to water, the need for prior instructions on how the game works and operates is considered redundant. As mentioned above, discovery learning occurs in the context of this DRPG game and students take control of when, what and how they want to learn Chemistry unintentionally, through the activities and the quest they complete in the game.

The instructions, task and requirements of the game focus on the responsibility of the players to actively solve problems, thus stimulating mental activities that lead to active learning (Randi & de Carvalho, 2013). This learning theory was popularized in the 1990s by the Association for the Study of Higher Education (ASHE) report (Bonwell & Eison 1991). Active learning engages students in two aspects – doing things and thinking about the things they are doing leading to students actively or experientially involve in the process of learning. In a DRPG, the continuous need to actively learn and construct new knowledge occurs when students engaged in game play find ways to gain rewards, defeat the boss and up their level and this in turns lead to discovery learning. This inquiry-based, constructivist learning theory discovered by Bruner (1961) proposes that learners construct their own knowledge through active participation that promotes motivation. The interactive nature of the digital RPG provides an immersive experience that stimulates creativity and encourages the development of problem solving skills to accomplish the mission given in the game. Players of the game also learn from the modeling approach found in the game. All these factors help students discover, construct, organize and categorize information.

The view of students actively constructing new knowledge through discovery learning leads to learning becoming meaningful. These in turn leads to students leveling up in the game and discovering more new knowledge as they actively solve new problems and master the game to level up some more. The loops in Figure 3.2 shows the repetitive nature of the game that allows students to master tracing of apparatus, crafting potions and bonding petticles as they level-up in the game. The double arrow at the end of the loops also showed that discovery learning and meaningful learning occurs concurrently through continuous game-play. In summary, the theoretical framework, as shown in Figure 3.2 has situated learning as the underpinning theory for the present study. Throughout the research period, Chemistry learning occurred when students were bouncing between discovery learning and meaningful learning as they continuously play and level up in the game. This also leads to students mastering the game. In all these, the social interaction aspect of Vygotsky's theory to maximize learning through the providence of a scaffold is investigated. The scaffold can come in the form of the teacher that acts as facilitator as well as an instructional guidebook provided midway through the study period.

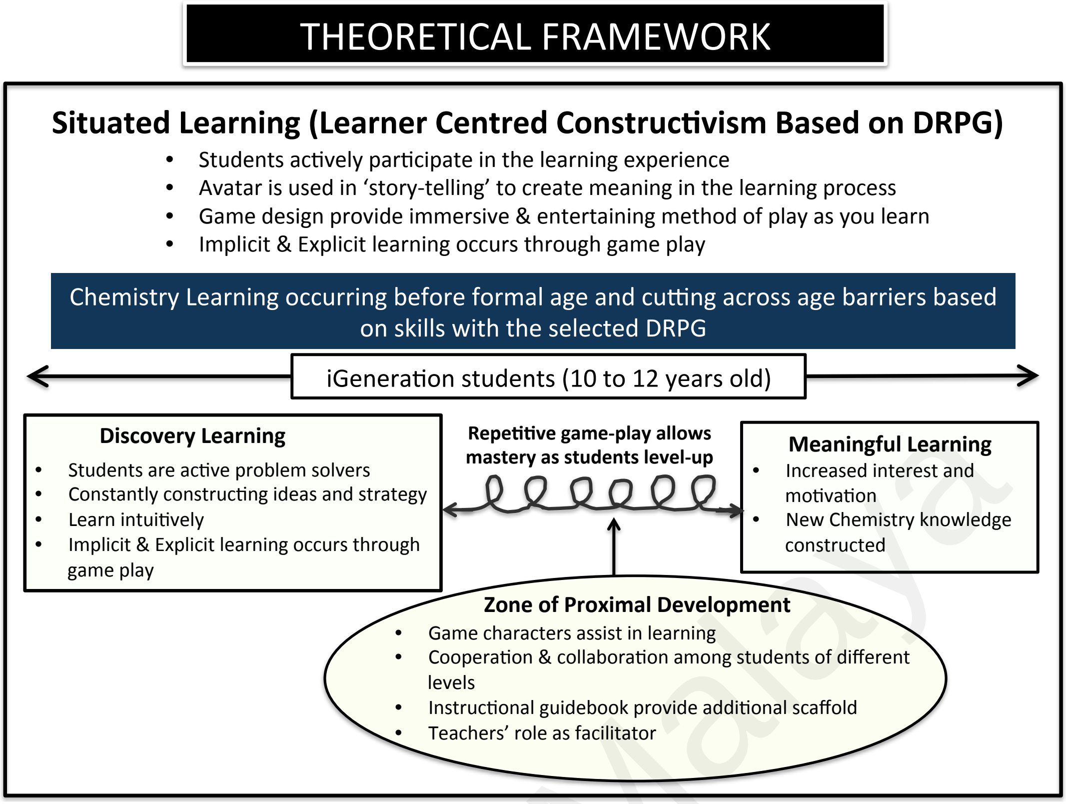


Figure 3.2: Theoretical framework for the study.

3.4 Chapter Summary

Research from previous studies show that prior knowledge of participants was a prerequisite. In addition, all studies were conducted on participants of the same age cohort and were at the right cognitive developmental stage. The conceptual framework of the present study was derived from gaps identified from previous studies and the use of ChemCaper fits into this gap in the sense that prior knowledge is not a prerequisite before playing this game. Besides that, Chemistry learning is non-linear and participants chosen have not obtain formal Chemistry education (not in the formal operational stage) and are not from the same age cohort. The next chapter will discuss the methodology of this study in detail.

CHAPTER 4

METHODOLOGY

4.1 Introduction

This study was designed to explore Chemistry learning using a selected DRPG found in the commercial market known as ChemCaper for the iGeneration. It has been agreed upon from previous research that although DRPG does provide the educational foundations much needed by the iGeneration, but these studies were limited to age-based learning and restricted to games designed by educators. In addition, studies did not investigate learning occurring across age and based on skills. This DRPG was chosen because this game was specifically designed from the collaboration between educators who emphasize on the need to have strong learning theories on Chemistry and professional game developers who look into the features needed in a game to produce the 'flow' that will attract players and keep them interested as they immerse in a virtual world of imagination.

The researcher adopted a qualitative research design based on Creswell (2014) to investigate claims from the developer on the ability of ChemCaper to reinvent Chemistry learning. The research methods adopted in this design included observations by the researcher and participants' teacher, focus group interviews, and online assessment to obtain thick, rich data that can be used to describe the participants' feelings, expressions, actions and opinions better as these data would provide a more detailed and accurate representation of how the game affects motivation of the participants. A qualitative approach is also required to elicit deeper insights and describe the various aspects on how reinvention of Chemistry learning can occur from playing ChemCaper. The data collected in a qualitative research are normally non-numerical and undergo rigorous and systematic methods to transcribe, code, analyse and triangulate to form trends and themes. In addition simple descriptive analysis was used to complement the qualitative data obtained. Thus this chapter is broken down to the following sections:

i.) A brief description of ChemCaper, the intervention Digital Game used in the present study.

ii.) The pilot study conducted by the researcher.

iii.) Reasons for modifications in the actual study

iv.) Developing the interactive online quiz assessment

v.) Methodology of the actual study.

vi.) Data analysis for the actual study

vii.) Chapter summary of methodology.

4.2 ChemCaper

ChemCaper is a Chemistry adventure single DRPG, which revolves around Roub Idyum (Rubidium), fondly called Roub, who crashed in a place called Camp Ungku (Kampung Ku). In ChemCaper, the player takes on the role of Roub and is tasked with accepting quest to help him find his way home. The game consists of three worlds, with the first world being Camp Ungku, the second world is ReacTa and the third world is SubRosa. The player starts with Camp Ungku and is required to accept the quest posed in each world to help Roub find specific items.

Once the player accepts the quest, the player needs to navigate in the game and interact with non-player characters (NPC) in order to find these items. The player is also required to fight alcyons (monsters) for the items and in the process get rewarded with points, cards, orbs (atoms), primers (spell books) and berries (ingredients to make potions). However, the player needs to plan and strategize battle combinations (Figure 4.1) using petticles (Table 4.2) and potions to win.

Figure 4.1: Different battle combinations produce different battle success rates.

Chemistry learning in this game is divided into three main sections, which are tracing apparatus, crafting potions and bonding petticles as listed below:

(i) **Tracing apparatus** (Figure 4.2): The player gets an apparatus by tracing the apparatus. The list of apparatus available in this game includes test tube, beaker, conical flask, filter funnel, thermometer, round based flask, separating funnel, fractionating column, centrifuge, tripod stand, retort stand with clamp, Bunsen burner and Liebig condenser.

Figure 4.2: Players need to trace apparatus repeatedly for use in crafting potions.

(ii) **Crafting potions** (Table 4.1): Potions are used to help fight alcyons (monsters) in the game. There are five types of potions that a player can craft, which is health, speed, accuracy, defense and damage potion. In order to craft potions, the player needs to have the apparatus and the right physical separation techniques such as sieving, filtration, decanting, distillation, separation of immiscible liquids, fractional distillation and centrifugation. Figure 4.3 shows the percentage of potion obtained during the crafting of a damage potion. In addition to the type of potion, the name of the potion obtained is dependent on how well the physical separation technique is conducted.

Table 4.1

Different types of potion are crafted using different physical separation techniques

Colour- Potion type	Potion name based on crafting performance	Apparatus Used	Physical separation techniques
Red- Health	Trifling cordial middling cordial rejuvenating cordial	Pestle and mortar, test tube, and centrifuge	Centrifugation
Blue – Speed	Fleetfoot draft Silver gust draft Blunk blink draft	Conical flask, separating funnel and retort stand with clamp	Immiscible liquid separation
Green – Accuracy	Focus pocus cognizance Unerring cognizance Future sight cognizance	Round bottomed flask, Conical flask, tripod stand, Liebig condenser, Bunsen burner and rubber tubes	Distillation
Yellow – Defense,	Tough bubble tonic Glass jaw tonic Aegis shell tonic	Pestle and mortar, filter funnel, filter paper, retort stand with clamp, beaker and conical flask,	Filtration
Purple – Damage	Herculean brew, Behemoth brew Dominating brew	Round bottomed flask, Conical flask, retort stand with clamp, thermometer, fractionating column, Liebig condenser, tripod stand and Bunsen burner	Fractional distillation

Figure 4.3: Instructions are given for players to know the steps required in conducting physical separation techniques such as fractional distillation.

(iii) **Bonding petticles (Figure 4.4):** In this game, petticles mean particles and Table 4.2 shows a summary of petticle names with the corresponding requirements to make the petticle, while Appendix C provides a more detailed illustration. To bond a petticle needed for battle (Figure 4.4), the player has to choose the correct card, orbs and one of the three types of chemical bonds, which are covabon (covalent bond), iobon (ionic bond) and metabon (metallic bond) in the "petcubator" (Appendix J).

Table 4.2
The type of bonds required to make petticles in ChemCaper

Covalent bonds (Covabon)		
Particle Name	**Petticle Name in ChemCaper**	**Description**
Nitrogen	Cryo	Two nitrogen orbs and one Cryo card is needed to make Cryo
Oxygen	Oxyto	Two oxygen orbs and one Oxyto card is needed to make Oxyto
Fluorine	Flowyn	Two fluorine orbs and one Flowyn card is needed to make Flowyn
Bromine	Brom Brom	Two bromine orbs and one Brom Brom card is needed to make Brom Brom
Water	Hizo	Two hydrogen orbs, one oxygen orb and one Hizo card is needed to make Hizo

Ionic bonds (Iobon)		
Particle Name	**Petticle Name in ChemCaper**	**Description**
Sodium chloride (Salt)	Sal-T	One sodium orb, one chlorine orb and one Sal-T card is needed to make Sal-T
Calcium oxide	Lymlyte	One calcium orb, one oxygen orb and one Lymlyte card is needed to make Lymlyte

Continued on next page

Table 4.2, continued

Mettalic Bonds (Metabon)		
Particle Name	**Petticle Name in ChemCaper**	**Description**
Sodium	Sodi-U	Three sodium orbs and one Sodi-U card is needed to make Sodi-U
Lithium	Lith	Three lithium orbs and one Lith card is needed to make Lith
Potassium	Ptassyum	Three potassium orbs and one Ptassyum card is needed to make Ptassyum
Calcium	Elcium	Three calcium orbs and one Elcium card is needed to make Elcium
Magnesium	Magness	Three magnesium orbs and one Magness card is needed to make Magness

Figure 4.4: Sal-T is produced when the player is able to choose the correct atoms (orbs) and right chemical bond.

4.3 Pilot Study

In the present research study, ChemCaper is the intervention DRPG and prior approval (Appendix D) was obtained from the University Malaya Research Ethics Committee (UMREC) by the researcher to use this instrument. Before the researcher embarked on the collection of data for the present study, a pilot study was first conducted to assess the intervention DRPG, testing of the online interactive quiz and the methods used in collecting data.

The purpose of the pilot study was to identify potential practical problems that may arise in the actual study (Leon et al., 2011; Teijlingen van, Rennie, Hundley & Graham, 2001). It also allowed the researcher to amend and modify the research methodology, as needed based on data collected and analysed from the pilot study. Participants selected for the pilot study were students from an English Language tuition centre in Subang Jaya to fulfill the pre-requisite of comprehension in English. At first, a total of 70 primary school students from this English Language tuition centre responded to an invitation to participate in the pilot study. These students came from different schools around the Subang Jaya community, including from Sekolah Kebangsaan (National Schools), Sekolah Jenis Kebangsaan (National Type Schools) and also private schools in Subang Jaya.

However, as students faced various issues, which are discussed in the later section under Reasons for Modifications in the Actual Study, only 35 students managed to down load the game and participated in the study as shown in Table 4.3.

Table 4.3
Sample population of students in the pilot study

Schooling Year	Age Group	Number of Respondents	Number of Participants
Year 4	10 years old	26	13
Year 5	11 years old	24	11
Year 6	12 years old	20	11

The duration of the pilot study was also lengthened to 4 weeks due to the hiccups faced by parents in downloading the game. The timeline to illustrate activities and events that occurred throughout the pilot study are recorded in Table 4.4.

Table 4.4
The timeline to illustrate the sequence of activities and events in the pilot study

Timeline	Description of activities/events that occurred
Before week 1	Consent form distributed and collected from interested participants. Students fill demographic forms and Kahoot pre-test quiz administered. Students were given a download voucher to download ChemCaper.
Week 1	Two Whatsapp groups were setup to facilitate communications among students and with teachers. Parents facing issues with downloading the game were addressed.
Week 2	First activity questions were posted through Whatsapp for students to participate. Inactive accounts and parents still facing problems were addressed.
Week 3	Second activity questions posted through Whatsapp for students to participate. Students with inactive accounts were removed.
Week 4	Third activity questions posted through Whatsapp for students to participate. Three focus group interviews were conducted, one on Friday and two on Saturday. Kahoot post-test quiz administered at the end of the pilot study.

The data collection instruments employed for the pilot of study included:

(a) A demographic questionnaire to explore participant's background (Appendix E) before the pilot study began.

(b) An online interactive pre-test quiz using Kahoot (Appendix F) to assess prior knowledge before the participants were given ChemCaper download voucher codes.

(c) Questions posed in the form of 'questivity' in the Whatsapp group (Appendix G) during the study period.

(d) Focus group interviews with students (Appendix H) and an online interactive post-test quiz using Kahoot (Appendix I) at the end of the pilot study.

The purpose of the demographic questionnaire was to address concerns that the participants may get assistance from parents or siblings that would skew the results, while the pre-test quiz was to assess participants' prior knowledge in Chemistry. To begin the pilot study, two Whatsapp groups were set up to facilitate communications among students and the three Science teachers involved in this study. The researcher set up two Whatsapp groups to reduce the big volume of messages that may inundate and frustrate participants if only one Whatsapp group was used. Each Whatsapp group had an initial of 35 participants (although respondents who did not download the game eventually dropped off from the Whatsapp group), three Science teachers and the researcher. The Science teachers involved in this study were also the Science teachers that helped to develop ChemCaper by contributing their Chemistry knowledge and expertise to the game developers. Hence, these teachers are conversant with both the game and the Chemistry content in the game to assist the students. The researcher set herself as an observer and was not involved in assisting or contributing towards communication with regards to game-play or Chemistry content. For students who did not own mobile devices, either their mother or father was included into the Whatsapp group to act as conduit for communication.

No formal teaching was conducted throughout the research period but every effort was provided to ensure scaffolds were provided and collaboration among the students were made possible. These efforts included:

(i) Informing and advising students to use the Chempendium, a digital instructional guide embedded in the game that acts as a scaffold throughout the research period.

(ii) Two Whatsapp groups that allowed students to interact and collaborate among themselves and with the teachers.

(iii) Science teachers involved in the study took turns to be stationed at the tuition centre together with the researcher everyday throughout the pilot study duration to provide additional support to students if needed when they come to the tuition centre for their classes.

The researcher recorded the amount of time spent on the game by each participant throughout the research period (Appendix P) through the login data to explore the motivation of the participants in learning Chemistry using ChemCaper, because according to Fabricatore (2007), a good game provides players with the right amount of challenge, mastery and rewards that they seek. Hence, if these activities in the game were able to capture the interest and sustain motivation of the player, the participants would be spending a substantial amount of time logged onto the game. The researcher also used observations collected from communications in the Whatsapp group and photos posted by participants as data for exploring motivation. In addition, questions from the focus group interviews (Appendix H) also sought to explore the motivation of students towards the game. These questions solicited the participants' opinion of the game and the Chemistry content learnt. Three focus group interviews were conducted at the end of the fourth week of the pilot study (Table 4.4). The focus group interviews sought to answer the first three research questions. However, the turnout for the focus group interviews were poor with the first focus group interview conducted at the tuition centre on Friday having only five participants. The second and third focus group interviews conducted in the morning and afternoon the following day (Saturday) had only four and three participants respectively. Figure 4.5 shows the second focus group interview, which had four participants. In total, only twelve of the 35 participants were involved in the focus group interviews.

Figure 4.5: The second focus group interview session conducted on Saturday

The first source of data collected included observations from the communication of the participants among themselves and with the teachers as well as the researcher in the Whatsapp group when teachers posed questions in the form of 'questivity' as shown in Appendix G. The second source of data collected was from focus group interviews conducted on the fourth week. The third source of data obtained came from the Kahoot pretest and posttest interactive online quiz results, which sought to assess the level of Chemistry knowledge attained. (Appendix I). Issues in data collection and other problems arising from the pilot study are discussed in the following section, while issues that arose pertaining to the interactive online quiz are discussed under developing the interactive online quiz assessment. For practical reasons, these issues faced were used to modify the procedures for the actual study.

4.4 Reasons for Modifications in the Actual Study

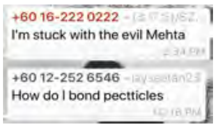
Results from the pilot study showed that only 50%(N=70) of the respondents actually played the game (Table 4.3). When the researcher inquired, reasons given for not downloading the game included lack of computer knowledge of the parent, computer incompatibility, no time to help their children, their children were busy and the Primary School Examination Assessment (UPSR, Ujian Penilaian Sekolah Rendah) was around the corner. Hence, one way to overcome these issues was to select a different set of participants that would not face such issues. This resulted in the decision to use an International school with computer facilities and students willing to stay back for an hour after school to eliminate lack of computer knowledge of parent, computer incompatibility, parent's busyness, students' extra curricular activities and UPSR issue.

Another modification to the actual study is having face-to-face interaction, which allowed for more teacher inclusiveness as facilitator. One notable finding from the pilot study was the fact that students had no problems mastering the game but lack the right guidance during game play to point them in the right direction and mitigate the conversion of implicit learning to explicit ones. For example, findings from the focus group interviews showed students relied on shapes, colour or position of the button when bonding a certain petticle. Below is an excerpt of conversation between the researcher and the focus group students

Researcher: "*Do you remember the types of bonds used to make the petticles?*"
Students: "*Shakes their heads*."
Researcher: "*So, which bond do you choose to make Brom-Brom?"*
Student Ace13: "*Oh, the one on the left…. I remember by position."*

(Focus Group Interview: 26 Aug. 2017)

It was also discovered that when students were allowed to play as and when they liked and without the presence of a teacher, students were ignorant to the importance of the NPC (non-player character) and the information imparted. For example, if the player took time to converse with the NPC, it would advise the player on how to bond petticles. However, excerpt from a Whatsapp conversation in Figure 4.6 showed player Ace 11 asking for help from the group:



Ace 7: I’m stuck with the evil Mehta
Ace 11: How do I bond petticles

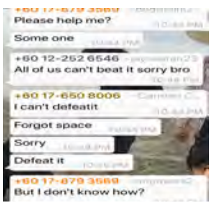
(Whatsapp Group 2 conversation: 8 Aug. 2017)

Figure 4.6: Player Ace 11 asked for help on petticle bonding.

In addition to that, data obtained from Whatsapp communications also showed the lack of scaffolding from teachers to provide guidance and motivation to keep students interested as they struggle with the game. For example, there were a few instances when students were asking for help and the delay in replies from teachers showed the lack of immediate support (Figure 4.7).

Ace 16: Teacher how can I defeat this?
Ace 21: Ya it’s impossible.
Ace 21: Is teacher online?
Ace 16: ?
Ace 10: Sooo hard my hand ache

Ace 21: I play 29 times but I lose
Ace 21: Almost 30
Ace 16: Tips please
Ace 18:I played forty and lose
Ace 21: Who has tips le?
Ace 21: Wow. 40?



Ace 16: Please help me?
Ace 16: Someone
Ace 18: All of us can’t beat it sorry bro
Ace 21: I can’t defeat it
Ace 16: But I don’t know how?

(Whatsapp Group conversation: 5-6 Aug. 2017)

Figure 4.7: Lack of teachers’ guidance and motivation to defeat the monsters

Hence, the presence of a teacher during game play would be beneficial to subtly challenge the students' thinking pattern and guide them with the right questions asked. This finding is supported by an earlier conclusion made by Squire et al. (2004), which was discussed in chapter two of the Literature Review. In addition, the relevant teacher would also be able to help students who may encounter technical problems.

Results from the pilot study also showed that the duration was lengthened to four weeks due to technical issues faced by parents who could not download the game for their children. However, with the actual study being carried out in the school lab of an International school, the duration for the actual study needed only two weeks. This was substantiated by login data collected from the pilot study, which indicated that most students could complete the game in about eight hours. Therefore a two-week duration with a total game-play of eight hours was sufficient for most students to complete the game.

4.5 Developing the Interactive Online Quiz Assessment

For the pilot study, the researcher developed two sets of online interactive Chemistry quiz using Kahoot as the assessment platform, one for pretest (Appendix F) to assess prior knowledge and the other posttest (Appendix I) to assess Chemistry knowledge attained from the game. The assessment items were developed based on Bloom's taxonomy of Cognitive domains and validated by the team of Chemistry teachers who helped to develop ChemCaper. Figure 4.8 shows sample of communication excerpts between the researcher and Chemistry teachers who helped validate the quiz items for the pre-test and post-test Kahoot quiz.

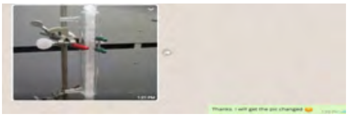
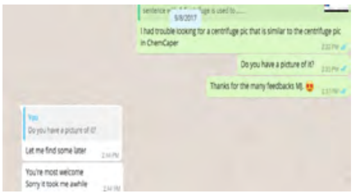
Whatsapp excerpts	Narrative from the Whatsapp excerpts
	MJ: Hi Linda, I’m looking through the Kahoot questions…This looks more like a condenser rather than fractionating column. Researcher: I couldn’t find a suitable pic. Do you have one that you can upload?
	Researcher: Thanks, I will get the pic changed.
	Researcher: I had trouble looking for a centrifuge pic that is similar to the centrifuge pic in ChemCaper. Do you have a picture of it? MJ: Let me find some later. Researcher: Thanks for the many feedback MJ. MJ: You’re most welcome. Sorry it took me awhile.
	Researcher: MJ, there is a limit to the word count. By the way, does the game mention about electrons or particles in the game? MJ: The petticle is a particle, but those surrounding one are electrons. Researcher: So, does that mean petticle can be atom, molecule or ion? MJ: Yes.
	MJ: Question 18, it is Bromine that show the deadly skull sign. Can put bromine in. Young kids may not know the word Toxic, maybe Poisonous sounds more familiar to them. (Whatsapp conversation: 5 June – 14 July. 2017)

Figure 4.8: Examples of communication excerpts between the researcher and team of Chemistry teachers from ChemCaper to validate the quiz items.

The researcher and Science teachers observed that when Kahoot (Figure 4.9) was administered as the online interactive quiz, some students were anxious when they did not know the correct answer, while others tend to look at their friend’s screen for answers. Besides that, it was also observed that students who scored wrong felt disappointed and demotivated when the screen showed they answered wrongly in plain view for everyone to see. From these observations and discussions with the teachers as member checks, the researcher concluded on using Google as the online interactive quiz assessment to address the problems faced in the pilot study.

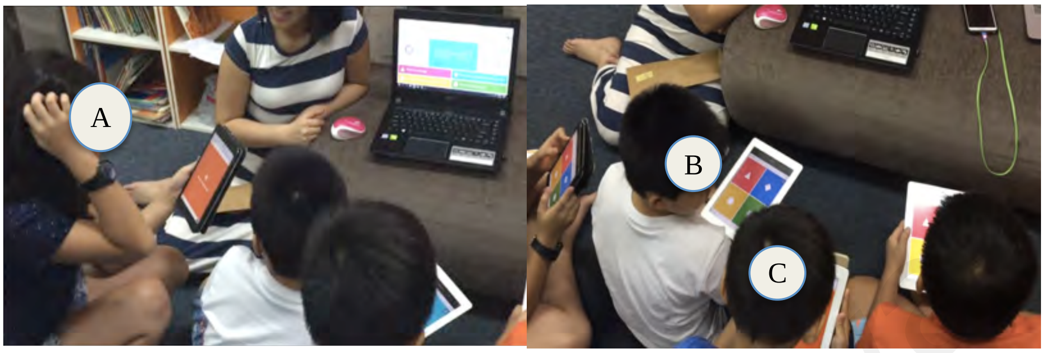


Figure 4.9: Student A scratched her head and showed disappointment when her answer was wrong while student B turned behind to look at student C's Kahoot answer.

Another reason for modifying the quiz assessment was because observations showed that students found Chemistry jargons in the online quiz assessments such as miscible, immiscible, covalent, ionic daunting and too difficult to understand at their level. For example, questions posed by students when Kahoot was administered included:

> Student Ace 16: *"Teacher, what is immiscible and miscible?"*
> Student Ace 7: *"Teacher, what is corrosive?"*
>
> (Kahoot administration: 25-26 Aug. 2017)

Therefore, many students did not understand the question posed nor the choices given as answers, especially when these questions were all built along intermediate Chemistry knowledge. In addition, Kahoot results from the pre-test and post-test pilot study (Table 4.5) did not show marked improvement in attainment of Chemistry knowledge. As such, the researcher decided to redesign the Chemistry questions to be built along the ChemCaper game.

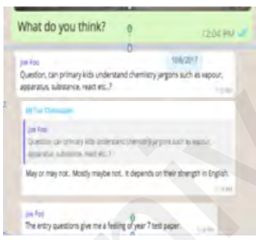
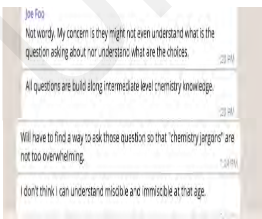
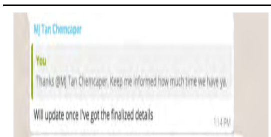
Table 4.5.

Comparison between Pre-test and Post-test Kahoot results

Pre-test:	
Less than 40% correct answers	10
Between 40-49% correct answers	17
Between 50- 59% correct answers	12
Between 60- 69% correct answers	4

Post-test:	
Less than 40% correct answers	10
Between 40-49% correct answers	9
Between 50- 59% correct answers	14
Between 60- 69% correct answers	5

In view that the question structures in the pilot study were too academic, technical and lacked visuals related to the game (Figure 4.10), especially for younger children who were unable to connect the dots, the researcher with the help of a game developer as advisor designed questions that were less technical and more connected with learning achieved from the game.

	Researcher: What do you think? JF: Question, can primary kids understand chemistry jargons such as vapour, apparatus, substance, react etc…? MJ: May or may not… Mostly maybe not.. it depends on their strength in English. JF: The entry questions give me a feeling of Year 7 test paper. J: Because it looks wordy?
	JF: Not wordy. My concern is they might not even understand what is the question asking about nor understand what are the choices. JF: All questions are build along intermediate level chemistry knowledge. Will have to find a way to ask those questions so that “chemistry jargons” are not too overwhelming. I don’t think I can understand miscible and immiscible at that age.
	Researcher: Thanks MJ. Keep me informed how much time we have ya. MJ: Will update once I’ve got the finalized details.

(Whatsapp conversations: 6-7 Oct. 2017)

Figure 4.10: Discussions with the ChemCaper team of teachers and programmer via Whatsapp messages to develop a less technical quiz.

The team of Chemistry teachers familiar with ChemCaper was consulted to validate the Chemistry questions of the online interactive quiz based on the Chemistry contents found in ChemCaper. Google doc was used as the new online interactive platform as students were more familiar with Google. Furthermore, students were given more privacy when attempting to answer the quiz compared to Kahoot used in the pilot study. Finally, with Google, immediate answers were not provided, as this was found to demotivate students (as shown in Figure 4.9, page 81).

4.6 Methodology of The Actual Study

Based on findings obtained from the pilot study that was discussed in the previous section, the researcher made necessary changes to ensure the actual study is well designed (Crosswaite & Curtice, 1994). This included adding a fourth research objective in the research study, which was to investigate the importance of scaffolding for the selected iGeneration students. As such, data collection method was changed from Whatsapp to face-to-face interactions. In addition, a different interactive online quiz assessment, which has been discussed in the previous section was developed using Google platform to address the issues faced by students in the pilot study. The methodology of the actual research study includes the following sections:

(i) Selection of sample

(ii) Duration of the study

(iii) Data collection techniques

(iv) Procedures of research

4.7 Selection of Sample

Results from the pilot study showed the need to have face-to-face interaction among participants and the teacher during the study period. As students with a good command of English were still the pre-requisite, the researcher chose to conduct the study in an International School, which uses the IGCSE (International General Certificate of School Education) curriculum. Besides having a good command of English, another pre-requisite fulfilled were these students have no prior knowledge of Chemistry. In addition, they were able to commit to participate for one hour after school everyday for the duration of two weeks. The method of sampling is still purposive sampling (Creswell, 2014) and students in Year 4, 5 and 6 who were interested to participate in the study were given forms to seek parental consent. The researcher sought to have a larger sample population. However, due to parent's apprehension on digital games benefitting their child's learning, the number of consents received was poor although interests among students were high. The total number of students who participated in the actual study was twenty (Table 4.6).

Table 4.6
Sample population of students in the research study

Schooling Year	Age Group	Number of Students
Year 4	10 years old	9
Year 5	11 years old	6
Year 6	12 years old	5

These students of different ages were grouped together and allowed to interact with one another during game play as this study intended to assess the learning of Chemistry across different ages.

4.8 Duration of Study

The duration of the research period for the actual study was two weeks, whereby the students were allowed to play the game for one hour after school everyday, from Monday to Thursday throughout the research period (Table 4.7). These group meetings were conducted in the Computer Lab after school hours with the presence of the participants' Science teacher, the computer lab assistant and the researcher as an observer. The methods of data collection to measure the Chemistry learning attained by the students across different ages are discussed under data collection techniques in the following section.

Table 4.7

The timetable planned for play and assessments for the duration of two weeks

Meetings	Monday	Tuesday	Wednesday	Thursday	Friday
First week	Play	Play	Play	Play	Focus group interview
Second week	Play	Play	Play	Play	Focus group interview /Interactive assessment

4.9 Data Collection Techniques

Data collection techniques for the present research study are as listed:

(i) Observations by the researcher via video recordings and daily journal of events observed throughout the two weeks period.

(ii) Focus group interviews with students at the end of the first week (Appendix K) and at the end of the second week (Appendix L).

(iii) Interview with the participants' Science teacher (Appendix M) on her observations of the students during game-play and in school.

(iv) Written assessments to assess Chemistry learning at the end of the first week (Appendix K) and at the end of the second week (Appendix L).

(v) An online quiz administered at the end of the second week using Google (Appendix O) to assess Chemistry knowledge attained.

Each and every data collection technique employed above is targeted to provide a more in-depth understanding to answer the research questions. For example, the use of video recordings besides daily journaling would provide a richer data to capture simultaneous complex activities and interactions in their natural setting. These recordings could be viewed and reviewed multiple times without losing its richness. Data analysis of the video recordings as discussed in the later section can be used to answer multiple research questions, including motivation, how the reinvention of Chemistry learning occurred as well as the importance of scaffolding. These video recordings also allowed the researcher to ask follow-up questions during the focus group interviews. Using the online quiz and written assessments allowed the researcher to assess the Chemistry learning attained from playing the game. However, it could not be used to explain how the learning was attained. This explains the reason for conducting focus group interviews as they allowed the researcher to understand how Chemistry learning could be attained.

4.10 Procedures of the Research

The present research study employed face-to-face interactions among the students as well as with the teachers. The physical presence of teachers as a facilitator during the face-to-face interactions is one of the requirements to investigate the importance of scaffolding for the selected iGeneration students.

With students having physical interactions among themselves and with the teachers as facilitators throughout the study period, the main source of data to capture the interest and motivation now came from the video recordings of the children while playing the game. Data collection also came from the researcher's daily journal and observations by the students' science teacher during the research period. In addition, questions pertaining to their opinion of the game and the Chemistry content learnt were asked during the focus group interview to explore the motivation of the selected iGeneration students in learning Chemistry using ChemCaper. The focus group interviews were conducted at the end of the first week (Appendix K) and at the end of the second week (Appendix L).

To evaluate how much Chemistry knowledge (basic chemical symbols, formulae and basic chemical bonding) the selected iGeneration students who have not been formally introduced to Chemistry curriculum have attained from playing the game, data was collected from the focus group interviews and the online quiz administered using Google.

The focus group interviews were administered at the end of the first week to assess students' prior knowledge of Chemistry, while the focus group interview conducted at the end of the second week after the end of game-play was to evaluate the amount of Chemistry learning attained. The focus group interview questions were broken into four sections (Appendix K and L) with the first section aimed at exploring motivation. In the second section, students were required to draw as many apparatus and name the apparatus they have drawn if possible, while the third section required them to write and describe the chemical processes involved to craft potions needed in the game. Both these sections are written assessments designed to measure ability to recall how to draw the science apparatus used in the game and physical separation techniques needed to ‘craft potions’ respectively. The final section of the focus group interviews seeks to understand how much Chemistry learning has occurred pertaining to Chemical bonds. Both focus group interviews were broken into two groups, with each group having an average of eight students after taking into consideration students who were absent.

Besides the focus group interviews, the online quiz using Google was used to evaluate Chemistry learning attained from playing the game. To ascertain that Chemistry learning had occurred from playing ChemCaper, the researcher interviewed the participants’ science teacher to gain more insight on the students’ prior knowledge of Chemistry.

As this study is aimed at understanding how ChemCaper can “reinvent” Chemistry learning, it is imperative not only to evaluate Chemistry learning attained but also describe how these students learn Chemistry at a tender age. Hence, the fourth research objective is an extension of the third research objective. Data used to describe reinvention of Chemistry learning come from video recordings and the researcher’s daily journaling on how the students interact among themselves to shed more light on how ‘reinvention’ occurs through their collaboration. Data from the focus group interviews (Appendix S) and the interview with the students’ teacher (Appendix T) were also used to assess students’ understanding and thought processes. Besides that, describing the reinvention of Chemistry learning also took into account results from the written assessment and interactive assessment to identify if there were any differences in Chemistry learning across age.

Besides student-teacher interactions, another significant intervention taken to investigate the importance of scaffolding for the selected iGeneration students during the research period was to introduce the instructional guidebook (Appendix N) to the students at the end of the first week as a form of scaffold. It must be noted that the digital form of the instructional guide is embedded in the game and students were encouraged to refer to it during game-play. Observations were recorded using the researcher's journaling and video recordings on the use of this guide in the second week. Questions from the focus group interview also touched on the students' opinions regarding the guidebook.

4.11 Data Analysis Method

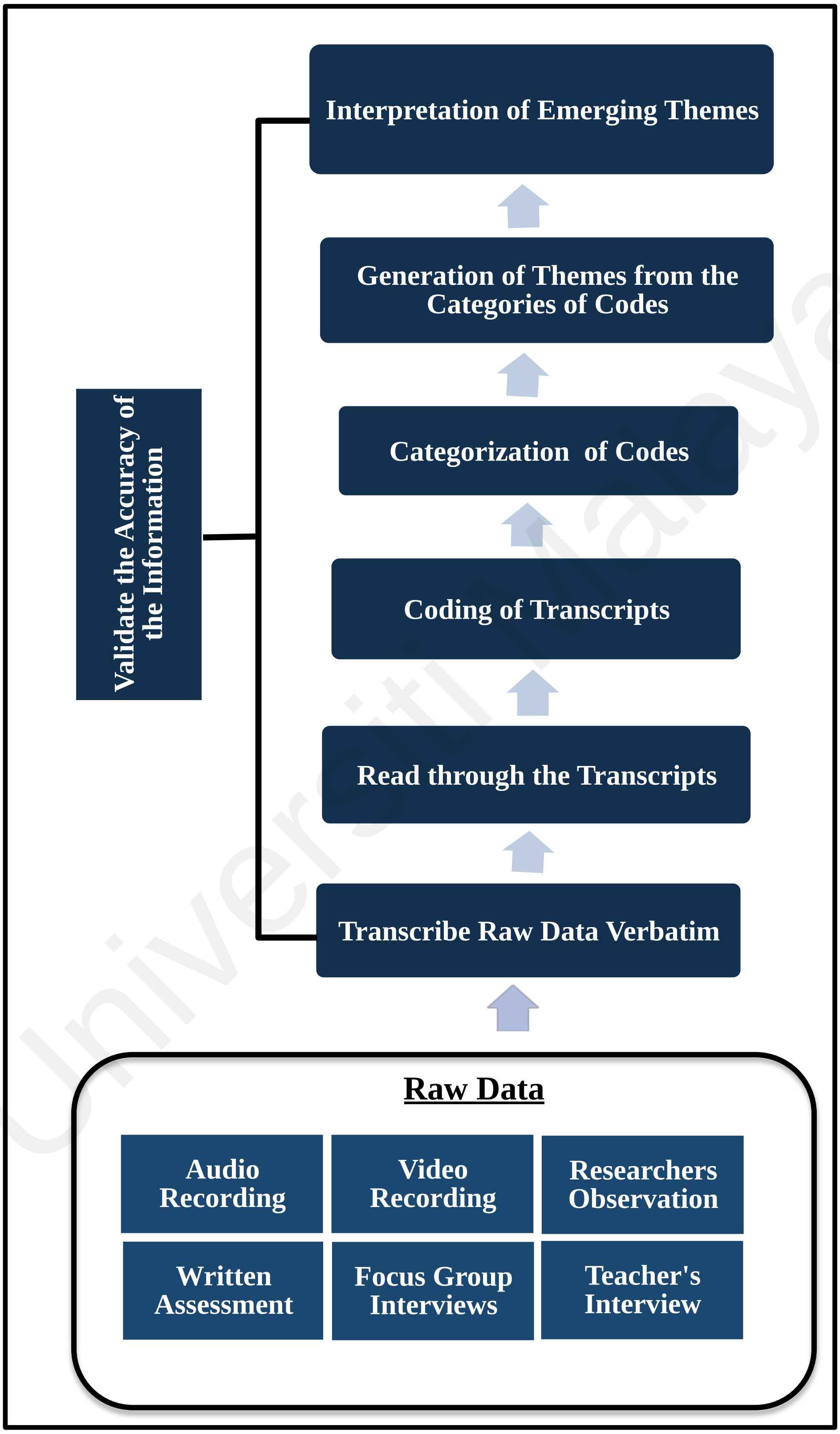
The analysis of data plays a pivotal role for the researcher to provide meaningful insight to the raw data obtained and explanation for the concepts and theories put forth in this study. As the data collected in the actual study came from various sources as discussed under data collection techniques, data analysis involved organizing and managing the raw data collected, breaking it into manageable units to draw out patterns and themes (Patton, 1990). The researcher decided to hand code the data collected although this method was both laborious and time consuming. Mirosoft Word documents were used to assist in the hand coding method. The following section discusses how the raw data were organized and managed.

4.11.1 Organizing and Managing Raw Data

The sources of raw data from the actual study that require transcribing and organizing include video recordings during game play, the researcher's journaling, interview with the students' Science teacher, audio recordings from focus group interviews and written assessments administered during the focus group interviews. An example of the video recording transcript is attached in Appendix Q. The researcher's journaling example is attached in Appendix R. The example of audio transcripts from the focus group interviews are attached in Appendix S, while interview with the students' Science teacher is attached in Appendix T. Table 4.8 summarizes the types of raw data collected and the process of data analysis conducted by the researcher, while the next section describes how the raw data is transcribed, coded and categorised.

Table 4.8

Organization and coding of raw data (Adapted from the work of Creswell, 2014)



4.11.2 The Importance of Video Analysis

During the course of data collection, the researcher discovered the many benefits of video recording above other methods such as journaling, audio recording and written assessment. Although one can transcribe speech from an audio recording, justice can hardly be done to describe actions, facial expressions, gestures, gaze, tone of voice and cadence that occur simultaneously unless captured in a video. According to Ramey et al. (2016), video recording captures much more than just both audio and visual data as it allows the researcher to take into account multiple perspectives of the data collected. For instance, from the video recordings, the researcher was able to observe the actions, facial expressions, gaze and gestures of student B that showed his anxiousness but a frozen screenshot shown in Figure 4.9, page 81 required descriptions to show his anxiousness.

Another added advantage of video data is the opportunity to play the video over and over again to have a more complete representation and understanding of the whole context. For example, in another video data, labeled as V10_Nov1 that lasted forty seconds, three students were seen synchronizing their game play in the foreground although ChemCaper is a single DRPG. Teacher MJ assisted them in their battle against the boss (chief monster). At the same time, student DE10 and DE16 were seen helping student DE9 with her battle combination. Next to them, student DE12 jumps excitedly as he battles with the boss, student DE10 goes over to cheer him on while other students gave a look while engrossed in their own game. Teacher Jac starts taking a video of their excitement while teacher J walks over looking excited. Meanwhile, the students in the foreground started raising their hands in jubilation as they win the boss. When student DE12 won his battle, he waves his hand, shouts and jumps up and down in jubilation as student DE10 also raises his hands and shouted excitedly while checking student DE12's rewards. A sequence of screenshots of the video, V10_Nov1 is shown in Figure 4.11 to describe the sequence of observations illustrated by the researcher. These screenshots do little justice to the unique analytical affordances that the rich source of video data provides.

Figure 4.11: Screenshots of video V10_Nov1 to show the rich data for analysis.

4.11.3 Data Transcription, Coding and Categorisation

All audio and video recordings captured via the researcher's mobile phone were downloaded to the researcher's computer to be kept for further analysis. Data analysis began by labeling the various sources of data. For example, in Figure 4.11 above, video V10_Nov1 means this video was the tenth video captured on November 1st. All these data were then transcribed verbatim using Microsoft Word and the videos were replayed to ensure all aspects of the observations were captured in transcriptions. Appendix Q shows an example of video recording transcripts, while Appendix R showed an example of the researcher's journaling. These transcripts along with the videos were then sent to the researcher's peers (mentioned in peer review under the reliability and trustworthiness) that acted as her panel for peer review. An example of the audio transcript from the focus group interviews is attached in Appendix S, while interview with the students' Science teacher is attached in Appendix T. The next step in the data analysis was to identify early codes from reading through these transcripts. The early codes were peer reviewed by the panel of peers and also validated by the students' Science teacher (member checks) as discussed by the researcher in the reliability and trustworthiness section. An example of identifying early codes from part of a transcript is shown in Table 4.9.

Table 4.9

Identification of early codes from video observations and descriptions

Video codes	Memo of video observation /description	Early codes
V1_Nov2	DE14 bought Magnesium orb and DE10, DE17, DE15 are discussing about his battle combo. The students are very familiar with the game and know Cryo is not suitable for winning battles in Reacta. When the researcher questions them, they agree that Sodi-U, Ptassyum and Brom brom is better in this section. DE15 writes and lends his combo book to his friends.	Intense discussion, familiarization, game mastery, game analysis, game planning and strategy, knowledge provider
V2_Nov2	The students are engrossed in their games and DE12 is excited to get a new petticle. DE10 congratulates DE12 with the new petticle (bitty Lith). At the same time, DE10 is checking the requirements to bond Sal-T. He then proceeds to choose the card, orbs and Iobon. He claps and cheers excitedly when he gets his first Sal-T and exclaims, "Yay! Finally! So cute".	Engrossed, immersed, engaged, excitement, encourage, collaboration, discussion, gains knowledge, joy, delight, cheers
V3_Nov2	The students check with each other which world they are in. DE13 asked his friends why DE17 is missing. DE18 asks DE15 for help with petticle bonding.	Collaboration, concern, teamwork, seek help, assistance
V4_Nov2	DE7 is helping DE8 with her battle combo and explains why he uses Cryo, Ptassyum and Oxyto in his battle combination.	Assistance, analysis and evaluation
V5_Nov2	DE7 announces his first gritty (level 3) Magness and this brings DE11 and DE16 to view it.	Excited, Sense of achievement,
V6_Nov2	DE10 is happy he can go to Xenon. DE12 is excited he got a new petticle, Flowyn. He does the dab. DE7 explains why he prefers to use Flowyn in ReacTa. DE10 also gets a new orb, Flowyn. He is so happy to get rewards by talking to the NPC. Both he and DE12 are at the same speed. He is excited to accept a new quest and can't wait to bond more Flowyn. At the background, DE7 is seen helping DE8.	Delighted, excitement, sense of achievement, game analysis, happiness, joy, cooperation and collaboration, teamwork, confident, scaffolding
V7_Nov2	DE10's confidence level is very high and he feels this winning is a piece of cake. He says "it is so easy you know". In the background, teacher J is helping DE8.	Confidence, elated, scaffolding, "so easy", guide, encourage

The early codes were numbered and the frequency of codes that appeared the same was recorded. Subsequently, codes that had similarities in their meaning of words, phrases or events were categorized together. Next, these categories were then analysed to generate themes and emerging themes based on the relationship between codes, the code frequencies and underlying meaning of these code that corresponds to the research objectives of this study. Peer discussions with the panel of peers, familiar with data transcription and coding were consulted to validate the early codes obtained in Table 4.9. These peers were also consulted to validate the generation of themes. For example, Table 4.10 shows the generation of themes to measure the first research objective, motivation for the actual study.

Table 4.10

Themes generated for motivation from the reduction of early codes

Themes		Reduction of early codes/data
Situational Interest	Engagement	Alert, focused, attentive, participative, responsive, engrossed, duration spent of playing, entertaining, intense discussion
	Flow Experience	Unwilling to shut down, complete engagement, craving for more, winning battles and getting rewards, Sense of accomplishment, Immersed
	Environmental factors	Teamwork, cooperation, collaboration, competition, support, inclusion, social acceptance
Active Participation		Ask questions, take notes, compare notes, plan, discuss, constantly exploring,
Challenges		Overcoming obstacles, preference towards certain petticles, competency, winning, rewards, developing battle strategy, makes effort to learn,
Positive Emotion		Satisfaction, Happy, alive, fun, excited, enjoyment, elation, jump and scream in excitement, do the dab, cheers, high five, jubilation, confidence, stimulated, delighted, assertive, encouraged, joy, curiosity, immersed, adventure, interested,
Self-efficacy		Well prepared, self efficacy to learn and master the game, analyses, planning & strategizing, keep records of battle combinations, monitors stock of apparatus and petticles, autonomy

To evaluate the Chemistry knowledge attained by the selected iGeneration students, the researcher put forth a list of criteria to measure the levels of attainment based on the Chemistry content found in ChemCaper. The list of criteria identified is as follows:

a) Students' ability to draw and list apparatus all 13 apparatus used in ChemCaper.
b) Students' ability to list all 7 physical separation techniques used in ChemCaper.
c) Students' ability to name all 5 types of Covabon (covalent bonding) found in ChemCaper.
d) Students' ability to name all 5 types of Metabon (metallic bonding) found in ChemCaper.
e) Students' ability to name all 2 types of Iobon (ionic bonding) found in ChemCaper.
f) Online Interactive quiz scores after completing the study duration.

Based on the deliberation between the researcher and panel of peers, the researcher developed a criterion-referenced assessment consisting of three levels to evaluate the Chemistry knowledge attainment by the selected iGeneration students as shown in Table 4.11. Each level of attainment is allocated a range of marks based on the students' ability as illustrated in the general description, which serves as a guide. The maximum accumulated score for the first five criteria is 32 marks and the range of acceptable marks to score a strong level of Chemistry attainment is between 22 and 32 marks coupled with an online interactive quiz core of 85% and above.

Table 4.11

The levels of Chemistry knowledge attained by the selected iGeneration students

Levels of Attainment	General description of each level of attainment
Strong Attainment (22 to 32 marks and quiz score of 85% and above)	i.) Can draw and name between 8 to 13 apparatus (13 marks) ii.) Can list between 5 to 7 physical separation techniques (7 marks) iii.) Can name between 4 to 5 petticles for Covabon (5 marks) iv.) Can name between 4 to 5 petticles for Metabon v.) Can name up to 2 petticles with Iobon vi.) Online interactive quiz score: 85% and above
Average to Good Attainment (10 to 21 marks and quiz score of between 60% - 84%)	i.) Can draw and name up to 8 apparatus, ii.) Can list up to 5 physical separation techniques, iii.) Can name up to 3 petticles for Covabon, iv.) Can name up to 3 petticles for Metabon v.) Can name one or both petticles with Iobon i.) Online interactive quiz score: 60% to 84%
Weak to Average Attainment (1 to 10 marks and quiz score of less than 60%)	i.) Can draw and name 4 or less apparatus, ii.) Can list 2 or less physical separation techniques, iii.) Can name less than 2 petticles for Covabon, iv.) Can name less than 2 petticles for Metabon v.) May not be able to name any petticles with Iobon vi.) Online interactive quiz score: less than 60%

To describe the reinvention in Chemistry Learning by the selected iGeneration students through playing ChemCaper, the researcher triangulated data from the audio and video transcriptions (Table 4.9, page 93), with the students' Science teacher interview and the students' levels of Chemistry knowledge attainment (Table 4.11). From the triangulation of these data, descriptions of each characteristic in the 'reinvention' of Chemistry learning are as shown in Table 4.12. The characteristics presented in Table 4.12 were the result after discussions with the panel of peers.

Table 4.12

Characteristics in the 'reinvention' of Chemistry Learning by the selected iGeneration students.

Characteristics in the Reinvention of Chemistry Learning	Descriptions of each characteristics in the reinvention of Chemistry
Attainment of Chemistry knowledge before formal Chemistry Learning	Students able to construct new knowledge through game-play, students have strong attainment of Chemistry knowledge and are able to explain
Attainment of Chemistry knowledge across age	Collaboration and cooperation across age to attain knowledge, MKO peers provide assistance, younger students are equal or more able to construct new knowledge compared to older peers, younger students are able to act as MKO,
*Head Fake (learning Chemistry by mastering the game) – emerging theme	(i) Strategizing skills to battle alycons and level up, (ii) Repetitive skills training to master drawing and naming apparatus, crafting potions and bonding petticles. (iii) Random learning based on situation and needs of player (non-linear learning of Chemistry).
Implicit to Explicit Learning – emerging theme	State type of bonds, able to connect petticle bonding with Chemical bonding, able to name or describe the apparatus needed and chemical process involved in crafting potions, explain the transfer of electrons, explain the sharing of electrons, meaningful learning, attainment of Chemistry knowledge from playing the game

*Head Fake – this form of indirect learning posited by Randy Pausch has been discussed in the introduction of chapter three, page 52.

Findings from the pilot study (discussed in page 71) pointed to the need for scaffolding to provide motivation, guidance and assistance that helped convert implicit learning to explicit learning. This led to the addition of an emergent research objective to investigate the importance of scaffolding for the selected iGeneration students. Hence, based on the identification of early codes from audio and video transcripts (example provided in Table 4.9) and focus group interview transcripts, the themes generated to investigate the importance of scaffolding for the selected iGeneration students are shown in Table 4.13. The themes identified by the researcher have been peer reviewed to ensure reliability and trustworthiness.

Table 4.13

Themes generated to investigate the importance of scaffolding for the selected iGeneration students.

Categories/Themes	Reduction of early codes/data
Motivator	High five, encouragement, guide, create interest,
Scaffold	Assistance, help, explain, knowledge provider,
MKO	Students seek help from, guide weaker students,

4.12 Trustworthiness of The Study

According to Lincoln and Guba (1985), the trustworthiness of a qualitative research is important in evaluating its worth. There are four aspects of trustworthiness that must be established:

(i) Credibility,

(ii) Dependability

(iii)Transferability,

(iv)Confirmability,

4.12.1 Credibiity

Credibility is the most important aspect to establish trustworthiness. It is the equivalent to internal validity in quantitative research and gives confidence to the truth of the findings (Lincoln & Guba, 1985). Strategies employed by the researcher to ensure credibility include:

a) Triangulation of data. The main strategy employed by the researcher to ensure credibility is triangulation of data. Different data sources are examined and the evidences obtained are triangulated. For example, the audio and video recordings of participants by the researcher are coded and triangulated with data from focus group interviews and data from interviewing the participants' Science teacher to investigate the interest and motivation of the selected iGeneration student on using ChemCaper.

b) Member checks. The data that have been transcribed and coded from the interview between the researcher and the students' Science teacher was emailed to her for feedback and to seek her confirmation on the trustworthiness of the researcher's interpretations of the findings.

c) Reporting contrary findings. The researcher conducted a pilot study to ensure that data collection methods were practical. Contrary findings that were opposing to the objectives of the research in the pilot study were presented and queried resulting in modifications of data collection methods in the actual study to ensure data sources collected were credible.

4.12.2 Dependability

In a qualitative study, dependability aims to ensure the research findings are consistent and repeatable. This can be achieved by ensuring the findings are consistent with the raw data collected and that other researchers would arrive to similar interpretations and conclusion when looking over the data. In order to ensure dependability, the research employed the following technique:

a) Audit trail. The researcher kept detailed records of the research paths. All data collected are dated and labeled for easy reference. For example, In Figure 4.11 the video is labeled V10_Nov1 to provide the researcher easy reference.

b) Peer review. The data analysis was discussed with a panel consisting two of the researcher's peers to verify the instrumentation and data collection techniques were reliable and dependable. The first peer is a lady who has just completed her doctorate degree and has eleven years of teaching Chemistry experience. The second is another lady who holds a Masters degree in Science Education with ICT (Information and Communications Technology) and has over five years of teaching Chemistry experience. The data collection techniques and analysis were discussed with both ladies via email and Whatsapp.

4.12.3 Transferability

Transferability corresponds to external validity and refers to the degree to which the research results may be generalized or transferred from the original research situation to other contexts or settings (Bitsch, 2005). This can be achieved by purposeful sampling and providing thick description of the research context and underlying assumptions that surround the data collection. The researcher used purposive sampling to ensure that the sample population fits the research objectives of the study. In addition, the following techniques were taken to ensure transferability:

a) Use of rich, thick description. Video recordings used allowed the researcher to capture actions, facial expressions, gaze and gestures that provided a rich, thick description of the context from the video analysis. In addition, multiple perspectives of the data collected could also be described as the video data could be replayed multiple times. The many benefits of using video analysis had been described in detail under the importance of video analysis, in the above section. Besides video recordings, audio recordings also allowed the researcher to provide to capture the various responses of students that at times occur simultaneously due to their candid nature during focus group interviews.

b) Clarify bias. One method to provide thick description is to provide a more detailed account during data collection. This includes explanation on reducing bias. The researcher set herself up as an observer and was not involved in providing scaffold during the research period. This ensures the data collected was not subjected to participant bias.

4.12.4 Confirmability

Confirmability refers to the degree to which the results could be confirmed or corroborated with others (Baxter & Eyles, 1997). Methods to ensure confirmability include audit trail, member checks and triangulation (Lincoln & Guba, 1985). All these methods have been discussed in previous sections.

4.13 Summary of the Methodology

In conclusion, the main objective of the study is not only to explore the possibility of using the selected DRPG to "reinvent" the way students learn Chemistry across ages, but also to study the ability of students who have not reached the formal operations stage to fully grasp the concepts of Chemistry through playing a digital game with the assistance of a teacher as facilitator. Table 4.16 shows the summary for the methodology and data analysis, while the next chapter presents the findings and discussions of the study.

Table 4.14

Summary of Methodology

Research Objectives	Research Questions	Data Collection Technique	Data Analysis Method
1. To explore the motivation of the selected iGeneration students to learn Chemistry using ChemCaper.	1. How is the motivation of the selected iGeneration students in learning Chemistry using ChemCaper?	i.) Video recording and daily journaling by the researcher. ii.) Interview data from observation by the students' Science teacher iii.) Focus group interview with the students.	a. Raw data were transcribed. b. Early codes were collapsed. c. Themes were generated. d. Data from various sources were triangulated to find common themes in interest and motivation
2. To evaluate the Chemistry learning attained by the selected iGeneration students who have not been formally introduced to Chemistry curriculum after playing ChemCaper.	2. What Chemistry knowledge has the selected iGeneration students attained after playing ChemCaper?	i.) Interview data from observation by the students' Science teacher ii.) Focus group interview with the students. iii.) Written assessment during interview. iv.) Results from the Google online interactive quiz.	a. Students' ability to draw and list apparatus. b. Students' ability to list the physical separation techniques. c. Students' ability to list types of Chemical bonds. d. Google online quiz results were scored

3. To describe the 'reinvention' in Chemistry learning from playing ChemCaper.	3. What is the 'reinvention' in Chemistry learning among the selected iGeneration students when they learn Chemistry from playing ChemCaper?	i.) Video observations and daily journaling by the researcher. ii.) Interview data from observations of the students' Science teacher. iii.) Focus group interview with the students. iv.) Written assessment during interview. v.) Results from Google online interactive quiz.	a. Raw data were transcribed. b. Early codes were reduced. c. Descriptions of characteristics of 'reinvention' in Chemistry learning identified. d. Students' levels of Chemistry learning used as comparative analysis to triangulate the characteristics.
4. To investigate the importance of scaffolding for the selected iGeneration students.	4. How does the presence of scaffolds affect the dynamics of learning for the selected iGeneration students?	i.) Video observations and daily journaling by the researcher. ii.) Interview data from observations by the students' Science teacher. iii.) Focus group interview with the students.	Video observations, daily journal and data from interviews were coded and themes generated.

CHAPTER 5

FINDINGS AND DISCUSSION

5.1 Key Findings

This chapter puts forth the findings and the discussions that entail each finding for each research objective of the present study. The findings of the study were obtained from the analysis of data collected from various channels as discussed in Chapter 4, Methodology.

Key findings from this study showed that students were very motivated to play ChemCaper. Situated learning occurred through “head fake”, whereby students thought they were playing and mastering a digital game without realizing they were actually learning Chemistry. The game had allowed the selected students to attain substantial amount of Chemistry knowledge even though they have no prior Chemistry knowledge and are below the cognitive age of learning Chemistry. In addition, Chemistry learning using ChemCaper was found to be non-linear and skills based instead of age based. Finally, the research also points to the importance of scaffolding in the selected students’ attainment of Chemistry knowledge. Figure 5.1 shows an illustration of the key findings while the following sections discusses these findings in detail.

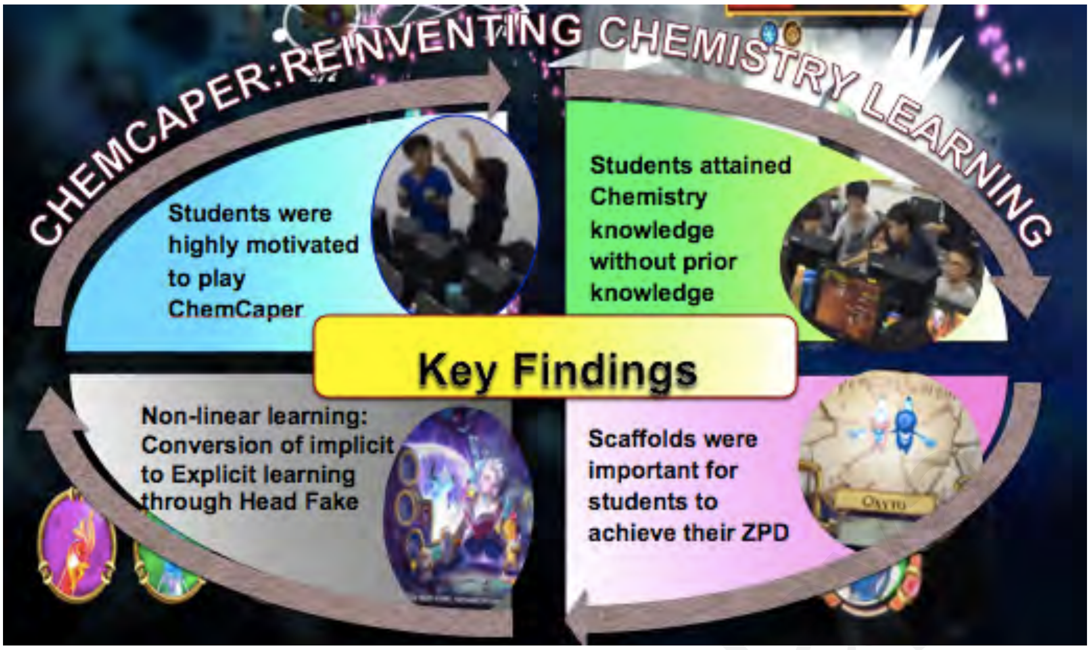


Figure 5.1: Key findings show the benefits of playing ChemCaper

5.2 The Motivation of the Selected iGeneration Students to learn Chemistry

In the first section of the analysis based on observational notes, interviews with the students' Science teacher, focus group interviews and video recordings collected on ChemCaper, themes were generated to capture the motivation of students while playing the game. In the following section, each theme is discussed in detail to answer the first research question while Figure 5.2 shows the summary of the themes generated.

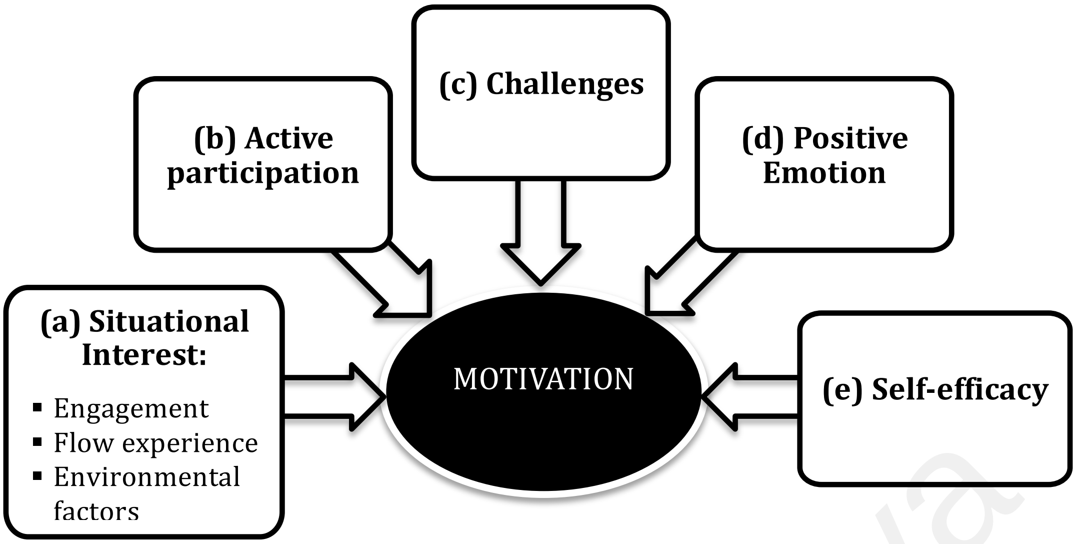


Figure 5.2: Themes generated for motivation among the selected iGeneration students

5.2.1 Situational Interest

It was discovered that situational interest played a very important role on influencing the students' intrinsic motivation to master the game and learn Chemistry. According to Schraw, Flowerday and Lehman (2001), an engaging game that provides the right amount of challenge creates situational interest, which in turn will increase the instrinsic motivation of students. The categories of situational interest include engagement, flow experience and environmental factors, as discussed below:

5.2.1.1 Engagement

Data from the video recordings showed that the focus and attention of the selected iGeneration students towards the game were intense. There was not a moment of boredom as these students played the game and if a picture is worth a thousand words, Figures 5.3 and 5.4 are screen shots taken to show a few examples of the engagement among students that goes on throughout the class sessions everyday throughout the study period. These screenshots show various actions and emotions such as being alert, focused, attentive, participative, responsive and engrossed. It also shows students are very entertained as they cheered and raised their hands in jubilation after defeating an alycon or the Boss. Students were seen constantly in intense discussion as they seek help from peers that were MKO.

Figure 5.3: A common scenario when students defeat an alcyon and receive their rewards**.**

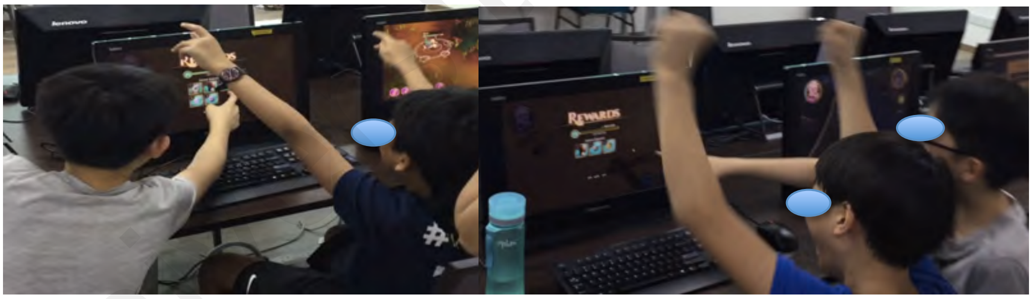


Figure 5.4: Students cheer and raise hands in jubilation after defeating the ‘boss’

Data collected from the focus group interviews and the science teacher’s observations showed similar results. An excerpt from the science teacher’s observations is as follows:

> *“They were very motivated and engaged. The game was very immersive for them and it made them determined to find ways to move forward in the game*”.
>
> (Interview with students’ Science teacher: 18 Nov., 2017)

While interview excerpts below show the thoughts of students about the game:

DE15: *"I like that you can spend your time playing a game and learn at the same time so you get like 2 in. I like that, it is also fun and exciting."*

DE5: *"We can fight and make many potions."*

(Focus Group Interview: 10 Nov., 2017)

5.2.1.2 Flow Experience

The researcher found from the focus group interviews that these students had a sense of accomplishment every time they defeated the Boss and moved on to the next level. In fact, video recordings showed students were completely engaged with the game from the moment they switched on the computer and many were unwilling to shut down when the time is up. Three students even came in a few minutes earlier to continue the game during the research period and when students were supposed to leave, many hovered to play a few more minutes. One student, DE13 asked for more time as he wanted to get into the next world. The researcher also noted that many students look forward to bonding Cryo as it was effective in freezing the alycons. In addition, the rewards they received for defeating alycons gave them the sense of achievement and 'feel good' factor. Two examples of student responses were:

DE11: *"I like fighting the alycons n boss but I get really nervous sometimes."*

DE9: *"We get to find these type of materials like oxygen, lithium, and then we can make them into particles that help us fight the monsters."*

(Focus Group Interview: 10 Nov., 2017)

This flow experience provided by the game prompted students to ask when the sequel for ChemCaper would be out during the focus group interview as shown in the excerpt below:

DE15: *"I just only ask teacher when is the other four chapters coming out."*

DE8: *"I want to know what happens"*.

(Focus Group Interview: 9 Nov, 2017)

Screenshots from Figure 5.3 and 5.4 further evidenced the complete engagement and flow provided by ChemCaper, especially when they received rewards from battle wins. This flow experience had been described by Csikszentmihalyi (1990) as a critical factor that keeps players interested as has been discussed under definition of terminologies (page 16) in the first chapter of this study.

5.2.1.3 Environmental Factors

Analysis of the researcher's journal showed the importance of other players to increase the interest towards the game. With the presence of other players, elements such as teamwork, cooperation, collaboration, competition and support come into play. These elements lend a hand to motivate players in various ways, for example, Figure 5.5 shows student DE7 helping student DE8 with her game. He has been helping student DE8 to play and understand the game better and this has helped to increase her motivation to play and learn Chemistry.

Figure 5.5: Student DE7 is seen advising student DE8 with her battle arrangement combination.

The researcher also noted that the motivation of student DE8 was affected when student DE8 was absent as was recorded in the researcher's journal:

> *Today, student DE8 was a little discouraged when student DE7 was missing as he has been helping her with her game play. She asked teacher MJ why student DE7 did not come.*
>
> (Researcher's journal: 1 Nov., 2017)

Another example of support, teamwork and inclusion can be seen in the right picture of Figure 5.6. In this picture, student DE15 was busy advising his friends, DE18, DE14 and DE13 on how to arrange their combo for battle.

In addition, the researcher found many students chose to synchronize their game-play even though ChemCaper is a single player DRPG (Figure 5.13). It is evident that the interest and motivation of players increased when they played together. This social inclusion allowed them to discuss, cooperate, collaborate and at times even compete with each other. A series of screenshots shown in Figure 4.11(page 94) under the importance of video analysis in Chapter Four captures the essence of the researcher's analysis. Supporting screenshots can also be seen in Figures 5.3, 5.4, 5.5, 5.6 and 5.13.

5.2.2 Active Participation

From the findings presented above, students were constantly seen grouping together to compare notes, discuss and ask each other or the teachers for help. For example, students DE2, DE3, DE5, DE6, DE8, DE9, DE10, DE11 had many questions as they played the game and needed assistance on science process skills when crafting damage potion that needed the use of the Bunsen burner and Liebig condenser. These students showed tremendous interest (in Figure 5.6) as they were trying to craft more potions and make more petticle to level up. Besides that, students who decided to synchronize their game-play were able to compare notes when they encounter difficulties. This move helped them to plan, discuss and explore more effectively as they get support from each other. Screenshots from Figures 5.3, 5.4, 5.6 and 5.13 showed evidences of active participation of players in ChemCaper.

Figure 5.6: On the left, two girls are seen discussing which potions to use and on the right, the boys are seen discussing battle combinations.

Interview excerpts with the students' science teacher also showed that she noticed them getting together in groups to discuss the game during schooling hours:

"Even in their classrooms and in the corridors…. they got together in a group, teaching and discussing the mechanics of the game and what they observed during game play."

(Interview with students' Science teacher: 18 Nov., 2017)

In addition, it could be concluded that as a result of active participation, fifteen out of the total number of participants (n=19) showed moderate to strong attainment of Chemistry knowledge as discussed in the next section. In conclusion, the continuous active participation of the students led to stimulating mental activities that allowed them to actively construct new knowledge through active learning as was proposed by Randi and de Carvalho (2013) in the findings of their research.

5.2.3 Challenges

At the onset of the research period, from the video recordings captured, the researcher could see that energy level were high among the students (screenshots in Figure 4.11, Figure 5.3 and 5.4). According to the game developer,

"One of the elements of ChemCaper is providing pleasant challenges to keep players interested and motivated to overcome these challenges."

(Conversation with game developer: 26 June 2017)

One of the outcomes of challenges faced is forming an affinity or preference towards a certain petticle. When probed in the focus group interviews, some responses received showed certain particles gave the players an edge in fighting battles. Some of the justifications recorded were:

DE10: *"Sal-T because he can last so many rounds. Like Cryo and everything can generally lasts about two rounds but Sal-T can last double that."*

DE9: *"I like Sal-T because he does a lot of damage."*

DE4: *"Gritty Magness and Cryo…. because these two make a combo really good."*

DE15: *"Everyone loves Magness… I put double gritty Magness and one cryo and I defeat all of them."*

(Focus Group Interviews: 9 and 10 Nov., 2017)

The challenges they experienced during game-play motivated them to find the best solution to win battles and from their analysis, evaluation and discussion with other players (Figure 5.6), they formed deductions why they preferred certain petticles to others. The rewards they received after defeating the alycons was also a motivation for them as shown in Figure 5.3 and 5.4. Focus group interview excerpts supporting these findings include:

DE11: *"I like fighting the alycons n boss but I get really nervous sometimes."*

DE8: *"I get to bond petticles and defeat bosses. Plus I love the rewards"*

(Focus Group Interviews: 9 Nov., 2017)

In addition, challenges encountered also helped developed student's willingness to learn and master the game as shown in the excerpt below:

DE16: *"The best thing is that you can make your own strategies on how to defeat the monsters."*

(Focus Group Interviews: 10 Nov., 2017)

According to Hamari et al. (2016), which was mentioned in Chapter three; constant developments of challenges in a digital game as player abilities grow could provide the immersion and engagement needed in learning. These data collected also supported the idea postulated by Resnick (1987) in Chapter two, literature review that motivated students would engage more easily in challenges through a realm of discovery learning to create meaningful learning.

5.2.4 Positive Emotions

Students were excited with the prospect of playing a DRPG. The students' teacher mentioned in an interview that students who were given permission by their parents to participate in ChemCaper kept asking her when the research would begin and were counting the days before it started, as they could not contain their excitement. According to the science teacher, this state of excitement was felt beyond gaming hours, during school-time as she noted that:

> *"The game made some students come alive and more willing to ask questions because they see their friends progress so they also want it and end up asking their peers or the teachers".*
>
> (Interview with students' Science teacher: 18 Nov., 2017)

She was also pleasantly surprised by the change in attitude of one boy named DE10, which she described as very quiet and reserved:

> *"DE10 is normally very quiet in class. He seldom speaks but after starting this game, he has become very chatty, more confident and interested in Science."*
>
> (Interview with students' Science teacher: 18 Nov., 2017)

Throughout the duration of the study, video recordings and journaling by the researcher found the class to be filled with positive energy as students chatted, sung songs and interacted with each other and the teachers while playing the game. For instance, Figure 4.11 (page 94), 5.3 and 5.4 showed students jumping with joy, waving their hands in happiness, doing the dab, cheering each other when fighting the Boss, encouraging each other with high five and screaming in excitement. In addition, the immediate intervention from friends and teachers, especially when fighting with the Boss helped encourage students and boost the confidence of students who were less competent.

In addition, students were seen chatting excitedly when they bonded certain petticles. The researcher found through dialogues with the students that many were drawn to the cute little petticles. Cryo (Nitrogen) was one of their favourite petticle for various reasons and examples of excerpts from focus group interview sessions to support were:

DE9: *" I like Cryo because it's strong, and the design is very cute."*

DE10: *"Cryo is my most favourite."*

DE7: *"The reason I like Cryos in Camp Ungku is because Oxyto does too less damage, and potassium is more for healing, so Cryos is the main option among these three."*

(Focus Group Interviews: 10 Nov., 2017)

At the end of the research period, focus group interview findings showed students were very interested in the game:

DE18: *"Teacher I got some more, I'd like to say that ChemCaper to me is a 5 star game for educational and fun purposes."*

DE14: *"No it's not 5 star it's 6."*

All students: *"One million stars!"*

DE13: *"Actually you know what, I'll give it infinity."*

(Focus Group Interviews: 10 Nov., 2017)

The researcher discovered two students had downloaded the game to continue playing at home, while student DE9 asked the researcher how to purchase the game as her father found the game had benefitted her very much and would like her to continue playing the game at home too. Besides that, all the students were asking for the sequel to ChemCaper. Excerpts of some conversations are as follows:

DE8: *"Teacher, I downloaded it already."*
DE3: *"Me too."*
DE10: *"Teacher, I'm waiting for ChemCaper 2!"*
Other students: *"Yeah, ChemCaper 2!"*

(Focus Group Interviews: 10 Nov., 2017)

Studies from Pew Internet Org (2008) found that almost all kids play digital games and most often than not, parents need to set limits to the amount of time played. One of the key findings from a longitudinal study conducted by Kaiser Family Foundation (2010) shows the time spent on playing games for children aged 8 to 18 have increased from an average of 26 minutes per day to over one hour in the last ten years. Another study conducted by Entertainment Software Association (2015) states that video games are ingrained in our society, while The Guardian (2013) reports that children spend significant time playing games online due to their interest.

5.2.5 Self-efficacy

The attribute of planning and strategizing were seen throughout the game-play period. These attributes included taking notes and comparing notes, planning, discussing battle combinations and strategies to gain the most points. Students also kept stock of their apparatus, potions and petticles in their inventory. In a screenshot shown in Figure 5.7, student DE15 can be seen recording his every battle combinations. During the focus group interview session, the researcher found that this is his fifth time playing ChemCaper and through his continuous exploration (discovery learning), he found that different battle combinations would produce different battle outcomes in terms of the strength of one's defense, damage done to the opponent and the value of points rewarded. His "battle combo" book had become the reference point for many of the other students as they consult him and each other when planning to battle the Boss and according to him, he discovers something new everyday:

DE15: *"My main account where I was in Sub Rosa, and I'm already close to finishing, and I had all the petticles so I decided to come up with all the combos so I know what to use, so I started writing down all the combos that I managed to make."*

(Focus Group Interviews: 10 Nov., 2017)

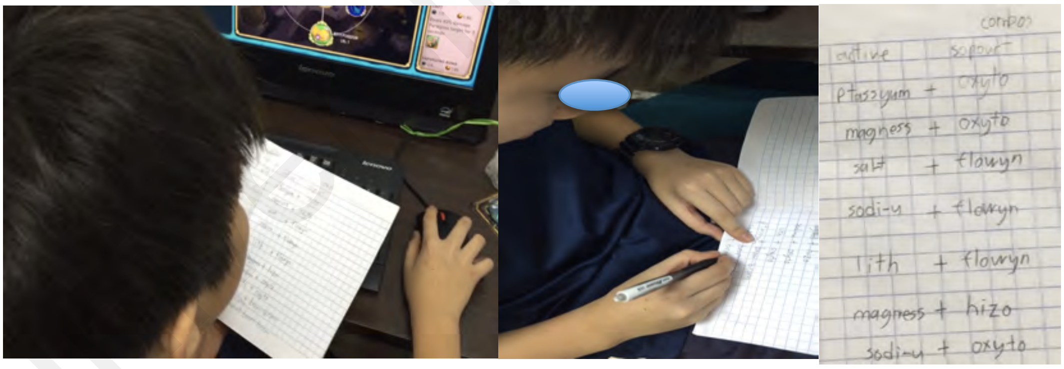


Figure 5.7: Student DE15 recording a new battle combination while strategizing his game-play.

According to Maehr and Meyer (1997), motivation shown towards specific goals can lead to an increase in effort and energy in activities related to their motivation. These efforts in activities can be clearly seen in student DE15 who actually took the initiative to record all his battle combinations for further use. Other students were also seen constantly grouping to discuss, plan and strategize in battle combinations and game-play as shown in Figures 5.6 and 5.13.

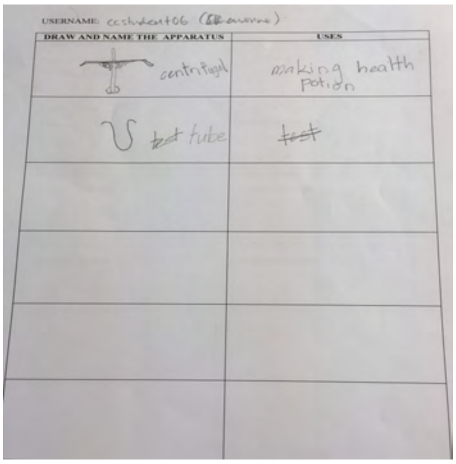
5.3 Chemistry Knowledge Attained by the Selected iGeneration Students

From the findings discussed in the previous section, ChemCaper has certainly met the expectations of the players to provide interest and keep them engaged and motivated to the point of students asking for the sequel to be produced. However, evaluation of the learning outcomes is also necessary to assess the knowledge attained among the iGeneration students.

Findings from the actual study showed that most students had no problem navigating around in the game with most students completing ChemCaper by the end of the study period. Students who encountered problems could easily ask friends and the teachers on duty for help. By the first day, most of them knew how to trace apparatus, make potions, fight alycons and bond petticles. Teachers were on hand to advise students and show them how to use the Chempendium as reference, especially for types of Chemical bond needed to bond petticles.

At the end of the first week, results from the focus group interviews showed some students have progressed better than others in recalling the apparatus they traced, potions they crafted and petticles they bonded, but most of them showed limited ability to draw apparatus and craft potions. For example, in Figure 5.8, the left picture showed the drawings and names of only two apparatus by student DE6 at the end of the first week. However, the same student was able to draw and name six apparatus at the end of the second week.

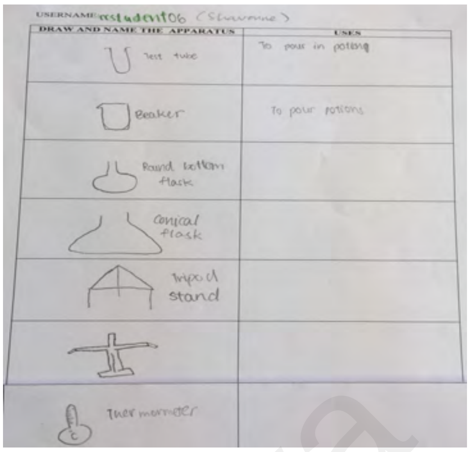
First week drawings



Description of the above drawing:

Centrifugal- making health potion.
Test tube

Second week drawings



Description of the above drawings:

Test tube- to pour in potions
Beaker – to pour potions.
Round bottom flask, Conical flask,
Tripod stand, Thermometer

Figure 5.8: Comparison of apparatus drawing and naming of student DE6

Knowledge of Chemical bonding was also limited knowledge as the researcher found that students relied on either colour or positions of the buttons to choose the right chemical bond when making petticles as shown in Figure 5.9.

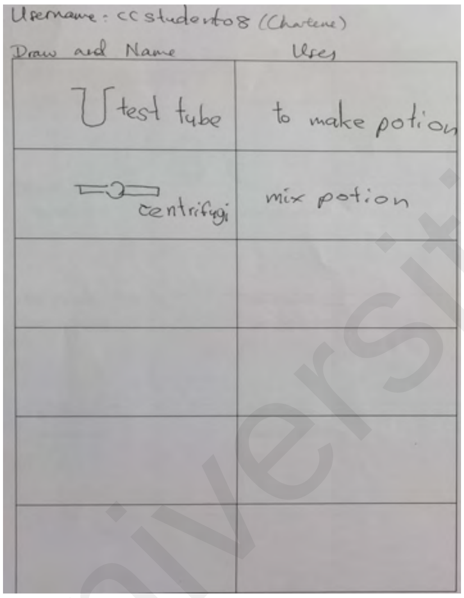
Figure 5.9: Petticles are made by choosing the correct combination of orbs, card and bond type in the 'Petcubator'

However, after the students were given an instructional guide called the ChemCaper Chempendium (Appendix N) at the end of the first week, Chemistry learning took a twist in the second week as students could now physically see all that they have been doing online offline. The researcher observed these books being passed around on the second week of game-play as those who forgot to bring their copies borrowed from friends. The beautiful pictures and illustrations caught their interest and the book became their point of reference throughout the second week. Students also became more aware of the Chemistry content in the game, as they were now using the terms Covabon, Iobon and Metabon more often during discussions and when asking friends for the right choice of bonds.

From the above findings, the knowledge about Chemical bonds did not materialize until the second week for most students. As discussed above, in the first week of the study, students relied on colour and position of buttons to choose type of bonds. From discussions held in the first week focus group interviews, many students were confused between the types of bonds needed to bond the different petticles. However, discussions from the second focus group interviews held in the second week showed many students were familiar and confident with the types of bond for each petticle mentioned in the interview. Students could answer in unison the three types of bonds they used in the game. In addition, they have connected the colour codes for each type of bond. For example, Covabon is blue colour and petticles with covabon are “oxyto, cryo, Brom Brom, Flowyn, and Hizo.

Besides that, the researcher also found that most students were able to list down the items needed to bond a petticle. As an illustration, student DE14 mentioned he used one oxygen orb, two hydrogen orb and one Hizo card to bond Hizo while student DE9 explained that she used two bromine orbs and a Brom Brom card to bond Brom Brom. Other students also took turns to explain what they used to bond Oxyto, Cryo, Flowyn accurately. This discussion was also conducted to examine the students' knowledge on Iobon and Metabon with similar results. Results from the second week focus group interviews showed a tremendous improvement on all three sections, which were drawing apparatus, crafting potions and listing types of Chemical bonds. This showed the occurrence of meaningful learning. Figures 5.8 and 5.10 shows two examples of marked improvement in apparatus drawings.

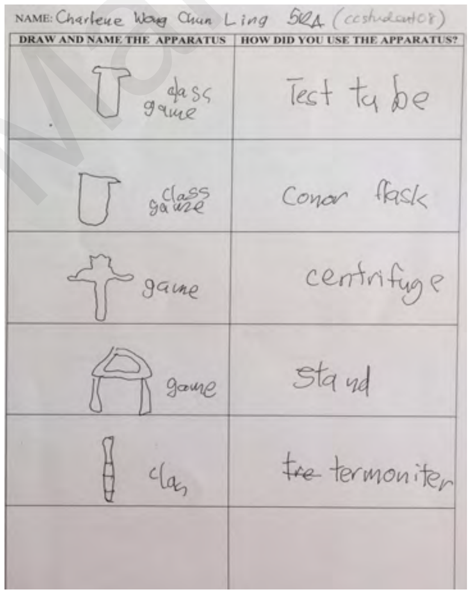
First week



Description of the above drawing:

Test tube- to make potion.
Centrifugi - mix potion.

Second week



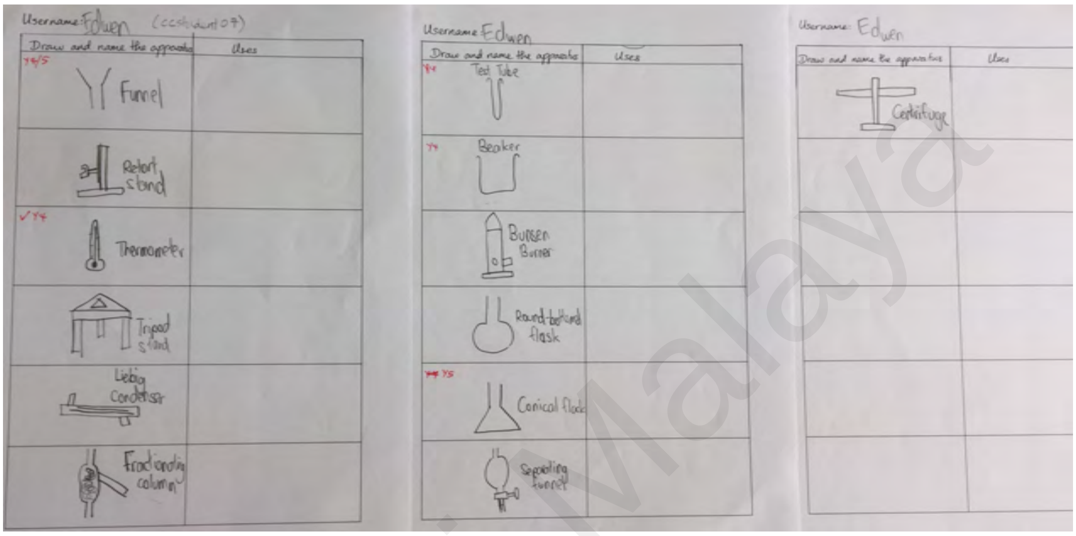
Description of the above drawing:

Test tube, Connor flask, Centrifuge,
Stand, Termoniter

Figure 5.10: Marked improvement in apparatus drawing and naming of student DE8

Two students who had played this game more than once were also able to recall all the apparatus they used and had comprehensive drawings and labels of apparatus found in the game as shown in Figure 5.11.

Apparatus drawing by student DE7 (10 years old)



Apparatus drawing by student DE15 (12 years old)

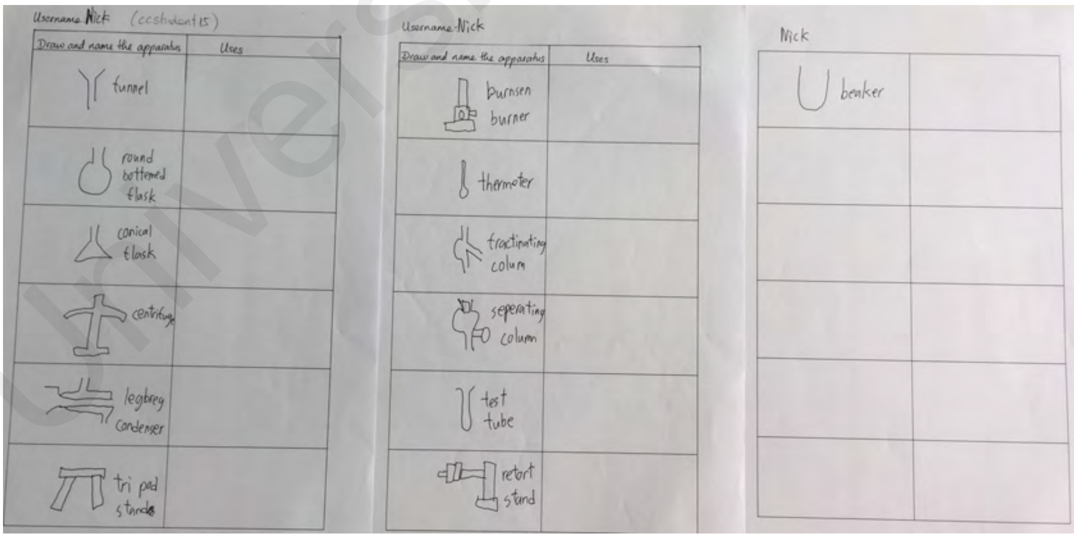


Figure 5.11: Comprehensive answers from two students who are extremely interested and highly motivated to play this game.

These two students were also able to recount in detail the different potions found in the game and some of the physical separation techniques needed, showing that meaningful learning occurred from game-play. For example, student DE15 said,

"There is the red color health potion, the blue color speed potion, the green color accuracy potion, the yellow color defense potion and the purple color damage potion."

(Focus Group Interviews: 9 Nov., 2017)

While student DE7 added,

"For the health potion there is the trifling cordial the middling cordial and the rejuvenating."

(Focus Group Interviews: 9 Nov., 2017)

When the researcher asked if they knew the apparatus needed to craft these potions, student DE15 replied,

"Yes, I remember all of them."

(Focus Group Interviews: 9 Nov., 2017)

While student DE7 candidly said,

"I know only for the middling and health potion because I craft it every single day."

(Focus Group Interviews: 9 Nov., 2017)

These replies clearly showed the repetitive nature of the game, which led to mastering of skills. These are just but a few examples to show how students have attained the knowledge of Chemistry with regards to identifying physical separation techniques such as centrifugation, decanting, liquid-liquid separation, filtration, distillation and fractional distillation required in crafting potions. A more detailed discussion of the potions listed by these students is presented in the next section and shown in Table 5.5. Besides tracing apparatus and explaining physical separation techniques, students were also able to explain what happened during formation of bonds. Findings on formation of Chemical bonds will also be discussed in the next section under describing the reinvention of Chemistry learning.

To ensure that students did not have prior knowledge before the research study begun, interview with the students' Science teacher revealed that her students only know the general parts of science and nature but do not have the vocabulary for Chemistry because they have not learnt Chemistry and it's not something tangible to them. But, when they started playing this game, she has observed subtle changes to some of these students. She mentioned,

> *"They became more daring and participative during lessons… more confident and willing to try something new".*
>
> (Interview with students' Science teacher: 18 Nov., 2017)

She further reasons,

> *"Could be because in the game it teaches them that it's ok to fail and it's ok to get wrong answers because it is through these failed attempts that they learn what is needed. And that lesson fits in very nicely in the Science and discovery world where there are many possibilities and unanswered questions".*
>
> (Interview with students' Science teacher: 18 Nov., 2017)

When asked if she felt they have gained any Chemistry from playing this game, her response was,

> *"Each student gained something from the game. Some more than others but all of them have learnt some form of Chemistry. The apparatus and names of elements are two examples of what was immediately engraved in their minds. The advanced students were able to connect the game to Chemistry better and realised that the petticles represented particles in elements and different elements bond with each other in their own unique way".*
>
> (Interview with students' Science teacher: 18 Nov., 2017)

The researcher found that the teacher's observations of her students were true, as two students have gained extensive knowledge on Chemical bonding as discussed under the reinvention of Chemistry section in this chapter.

Finally, based on the evaluation of students' knowledge of Chemistry attainment via the online interactive quiz, it was found that most respondents did attain some Chemistry knowledge from the game. The Chemistry knowledge attained by the students was divided into three levels as discussed in the Methodology section and illustrated below:

(i) Strong Chemistry knowledge (22 – 32 marks and 85 % and above)

(ii) Average to Good Chemistry knowledge (10 – 21 marks and 60% to 84%)

(iii) Weak to average Chemistry knowledge (1 – 10 marks and less than 60%)

The summary of the online interactive quiz results shown in Table 5.1 saw six students (n=19) with strong attainment of Chemistry knowledge, while nine students were graded with moderate Chemistry knowledge. Only four students had scores from 50.4% to 57.9% and were considered to have weak Chemistry knowledge. Although the total number of participants in this study was twenty students, only nineteen students took the online Google interactive quiz as one student had an accident after school and was rushed to the clinic.

Table 5.1:
Summary of the online interactive quiz results

Student Code	Age	Total questions	Total correct answers	% of correct answers	Chemistry Attainment Level
DE1	10	12	9.00	75.0	Moderate
DE2	10	12	7.83	65.3	Moderate
DE3	10	12	6.75	56.3	Weak
DE4	10	12	10.00	83.3	Moderate
DE5	10	12	6.05	50.4	Weak
DE6	10	12	6.91	57.9	Weak
DE7	10	12	12.00	100	Strong
DE8	11	12	6.82	56.8	Weak
DE9	10	12	12.00	100	Strong
DE10	11	12	9.50	79.2	Moderate
DE11	11	12	9.49	79.1	Moderate
DE12	11	12	8.00	66.7	Moderate
DE13	12	12	8.50	70.8	Moderate
DE14	12	12	11.50	95.8	Strong
DE15	12	12	11.75	97.9	Strong
DE16	11	12	12.00	100	Strong
DE17	12	12	11.16	93	Strong
DE18	12	12	8.16	68	Moderate
DE19	11	12	10.00	83.3	Moderate

When the online quiz results were analysed based on questions, knowledge attained from identifying apparatus is higher than knowledge gained on physical separation techniques and chemical bonds (Appendix U). For example, from results shown in Appendix U, all 100% (n=19) respondents could identify a test tube correctly, while 84.3% (n=19) could state the name of a beaker and 58% (n=19) students were able to name a centrifuge correctly. Besides that, 78.9% to 94.7%

(n=19) respondents could match the correct pairs of apparatus correctly while 84.2% to 100% (n=19) respondents could identify the correct apparatus needed to craft a certain potion.

In the chemical bonding section, about 78.9% (n=19) respondents knew that sodium chloride has ionic bond and 73.7% (n=19) knew calcium oxide has ionic bonds. It should be noted that students only started learning how to make calcium oxide petticles in the second week when they were in the second world of the game. The knowledge for metallic bonds was also considered high with 73.7% (n=19) of students identifying calcium and potassium to have metallic bond correctly.

According to Bellotti et al. (2013), both the player engagement, motivation and learning outcomes should be assessed to evaluate the effectiveness of a DGBL. In addition, Stewart et al. (2013) noted that DGBL could be classified into special purpose games, which have been developed solely for education and commercial-off-the-shelf games that were developed for entertainment purposes, but are being used in an educational context. As discussed under literature review, special purpose games usually lacks appeal to provide the immersion and engagement while commercial-off-the-shelf games would normally have to be adapted to suit certain learning sections. According to the developers of ChemCaper, this digital game is a merger of both classifications. Hence, it is the first DRPG with sound pedagogical theories in Chemistry to be commercially marketed, which falls under the digital role-play game genre.

5.4 The Reinvention of Chemistry Learning Among the Selected iGeneration Students

When the researcher interviewed one of the game developers before the start of data collection on why he felt ChemCaper game was different from other DGBL, his response was,

> *"The game content is obtained from the Chemistry teachers as they explain to the game developers what they want the students to learn and feel. This learning content is broken down into learning scopes from each chapter based on the Chemistry syllabus."*

(Interview with game developer, 23 June 2017)

With this information, the game developers then merged game elements with learning to make it less topical and removed the mundaneness of learning while inserting the flow and fun of playing. This ensures students enjoy the game without them realizing that they have been learning Chemistry.

5.4.1 Attaining Chemistry Knowledge before Formal Chemistry Learning

Results from this study have provided more insight on how playing this game has revolutionized Chemistry learning for these students who have not been formally introduced to Chemistry learning. The researcher found that learning was student-centred with students taking charge of their learning process as structured teaching was not conducted. There was no issue of boredom, student inattentiveness, lack of participation or even negative perceptions such as Chemistry is difficult throughout the study period. In contrast, students were excited and highly motivated to play

ChemCaper and learn Chemistry as discussed in the above section. This difference in approach towards learning Chemistry has allowed students to have a positive perception towards learning Chemistry. Comments from students to show they enjoyed learning Chemistry from playing the game included:

DE7: "ChemCaper is interesting and you can learn at the same time. It's always like very exciting."

DE15: "I like that its like also a role playing game and like you can spend your time playing a game and learn at the same time so you get like 2 in 1 like that, its also fun and exciting."

(Focus Group Interviews: 9 Nov., 2017)

Another point to claim that ChemCaper had reinvented Chemistry learning is the fact that prior knowledge of Chemistry was not a pre-requisite as opposed to previous studies discussed under past methodologies using DRPG in education in chapter two. To this end, ChemCaper does not support Piaget's notion that development precedes learning as the students in this study were well below the age of learning Chemistry formally. Findings discussed in the following sections support this notion that students below the age of formal learning were able to attain substantial Chemistry knowledge. One contributing factor could be due to the repetitive nature of the game that provided students with enough practice to master various aspects of the game, which included drawing and naming of apparatus, crafting potions and bonding petticles (as described in ChemCaper under methodology).

When students were asked to draw and name the apparatus they used in the game in the second week focus group interview, many could easily draw and list the apparatus. Some of the drawings are as shown in Figures 5.8, 5.10, 5.11 and 5.12.

Although there were some spelling errors here and there, but many of them could draw and name test tube, beaker, thermometer, filter funnel, retort stand, tripod stand, conical flask, round-bottomed flask, Bunsen burner, and even more difficult ones like separating funnel, fractionating column and Liebig condenser. When the researcher checked with the students' Science teacher, the researcher found that most of the apparatus they drew were learnt solely from the game, except for the few common ones like test tube, thermometer, beaker and conical flask.

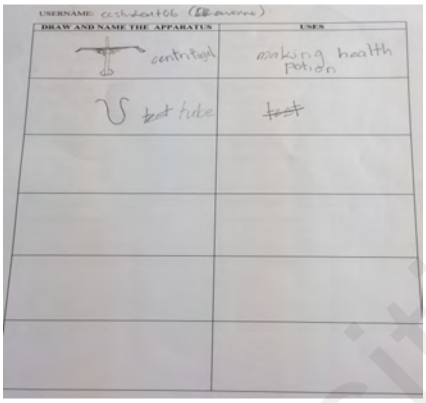
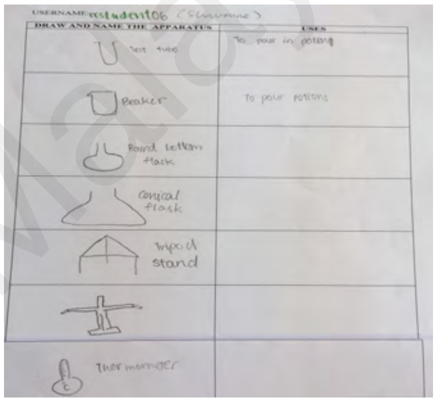
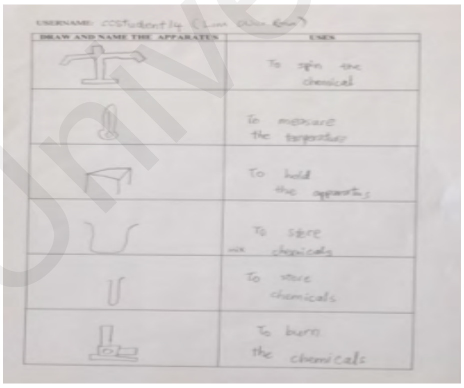
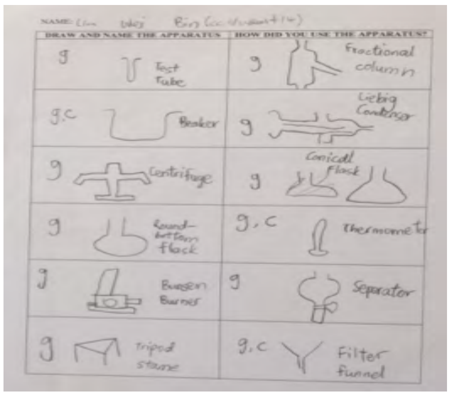
Student DE6: First week	Student DE6: Second week
	
centrifugal, test tube	beaker, test tube, tripod stand, conical flask, thermometer
Student DE14: First week	Student DE14: Second week
	
To spin the chemical, to measure the temperature, to hold the apparatus, to store mix chemicals, to store chemicals, to burn the chemicals	test tube, beaker, centrifuge, round-bottom flask, Bunsen burner, tripod stand, fractional column, Liebig condenser, conical flask, thermometer, separator, filter funnel

Figure 5.12: Students were able to draw and label more apparatus after two weeks of game-play

Results from the second week focus group interviews also showed notable attainment of crafting potions knowledge as shown in the discussion of the online interactive quiz results (page 123) and focus group interview excerpt (page 120 to 121). Although most students could only state the names of the different potions used, some could draw and name the apparatus used to make the potions. Two students could even name the physical separation techniques required to make these potions, which have been discussed in detail in the next section.

After two weeks of game-play, almost all students were able to state the type of bonds needed for the petticles they made. For example, Table 5.2 shows the answers provided by different students when asked to give an example of a covabon petticle and what they used to make that petticle.

Table 5.2

Students providing explanation for petticles with covabon (covalent bond)

Student Name	Petticle	Explanation
Student DE8	Hizo	Two hydrogen orbs, one oxygen orb and one Hizo card.
Student DE18	Cryo	Two nitrogen orbs and one Cryo card
Student DE10	Oxyto	One oxygen card and two oxygen orbs
Student DE14	Brom-brom	Two bromine orbs and one Brom Brom card
Student DE13	Flowyn	One Flowyn card and two flourine orbs

Students were also able to give explanations for iobon (ionic bond) and metabon (metallic bond) as shown in Table 5.3 and Table 5.4 respectively.

Table 5.3

Students providing explanation for petticles with iobon (ionic bond)

Student Name	Petticle name	Explanation
Student DE5	Sal-T	One sodium orb, one chlorine orb and one sal-
Student DE14	Lymlyte(fondly known as lime-lime)	One calcium orb and one oxyto card with one lime-lime card

Table 5.4

Students providing explanation for petticles with metabon (metallic bond)

Student Name	Petticle name	Explanation
Student DE3	Bitty-Lith	Three lithium orb and one Lith card.
Student DE17	Ptassyum	Three potassium orb and one Ptassyum card.
Student DE16	Sodi-U	Three sodium orb and one Sodi-U card.
Student DE5	Elycium	Three calcium orb and one Elcium card.
Student DE6	Magness	Three magnesium orb and one Magness card.

5.4.2 Attainment of Chemistry Knowledge Across Age

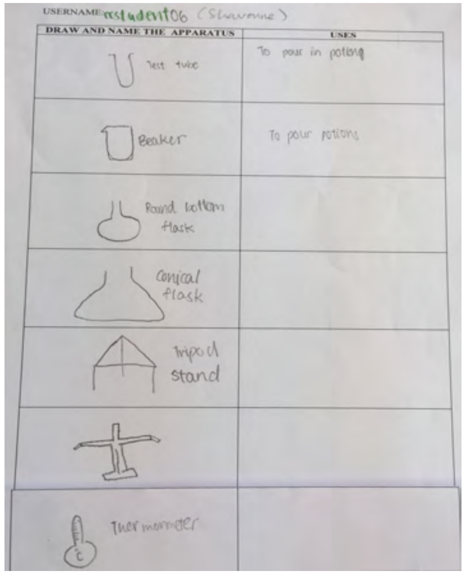
It was noted that students benefitted remarkably from face-to-face interaction among students and with the teachers. The cooperation and collaboration among students across age observed throughout the study period enhanced the learning process. Figures 5.3, 5.4, and 5.6 not only showed the interest and motivation of students toward the game but also the cooperation and collaboration among students of different ages as they were seen constantly engaged with each other, discussing about the game throughout the study period as is also shown in Figure 5.13.

Figure 5.13: The left picture shows a younger student helping his older peers while the right picture shows constant cooperation and collaboration among students

As mentioned previously, although this is a single player DRPG game, for some students, synchronizing their game meant they had assistance from more knowledgeable peers even though the MKO may be younger (shown in Figures 5.3, 5.6 and the right picture in Figure 5.13).

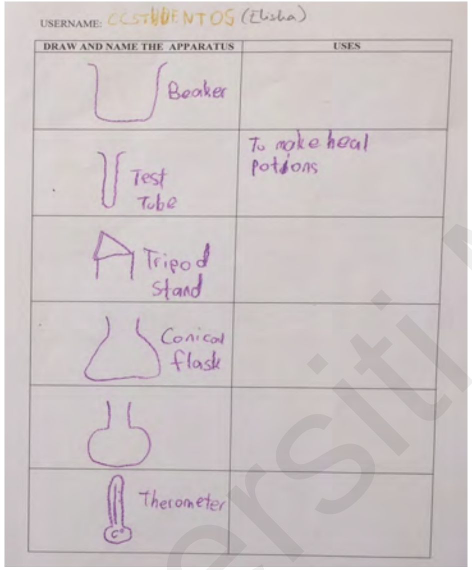
Figure 5.14 shows a comparison of apparatus drawings for the different age groups. Drawings from three students in each age group were selected and findings showed that except for some spelling errors, there are no notable differences in apparatus drawing for the different age groups. In other words, the Chemistry learning attained for apparatus drawing was not dependent on age. An even more interesting observation to note was that one ten-year-old boy, DE7 could draw and list all the apparatus better than his older peers as shown in Figure 5.14.

Apparatus drawings by three ten year old students



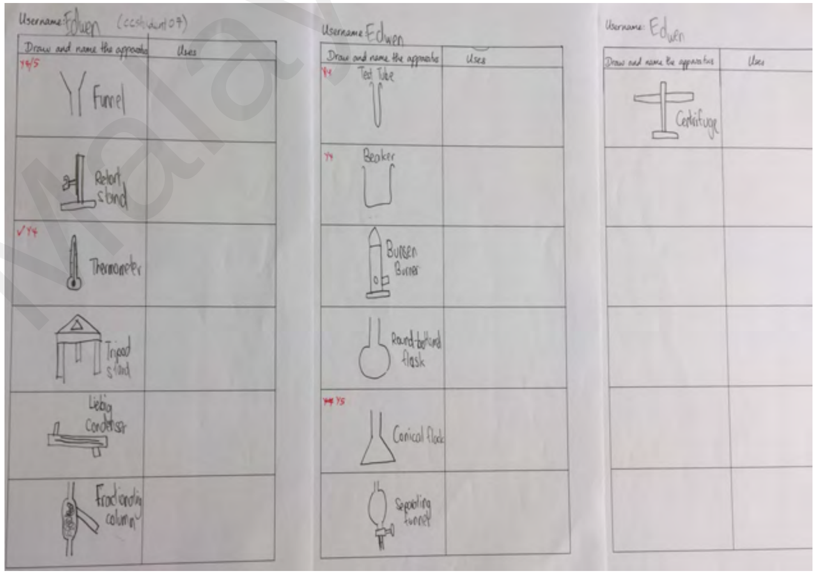
Student DE6

test tube, beaker, round bottom flask, conical flask, tripod stand, thermometer



Student DE5

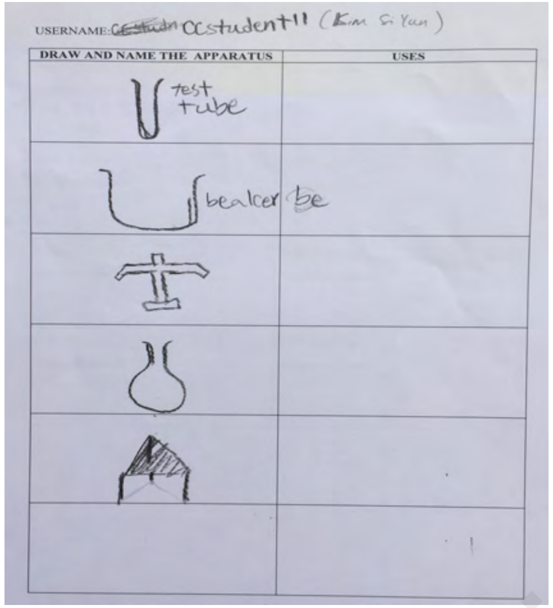
beaker, test tube, tripod stand, conical flask, thermometer



Student DE7

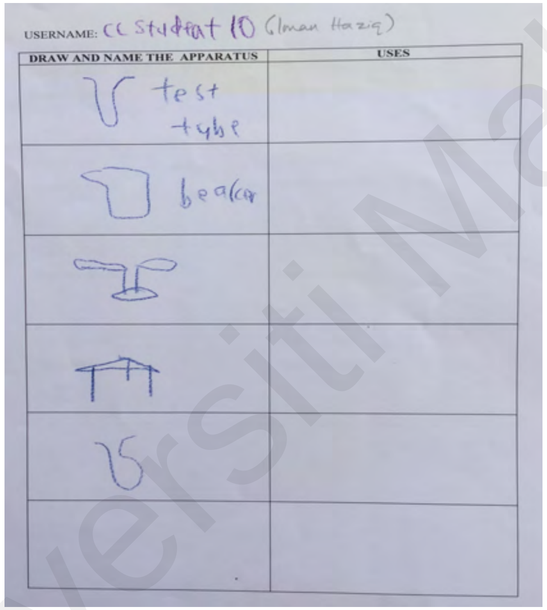
funnel, retort stand, thermometer, tripod stand, Liebig condenser, fractionating column, test tube, beaker, Bunsen burner, round bottomed flask, conical flask, separating column, centrifuge

Apparatus drawings by three eleven year old students



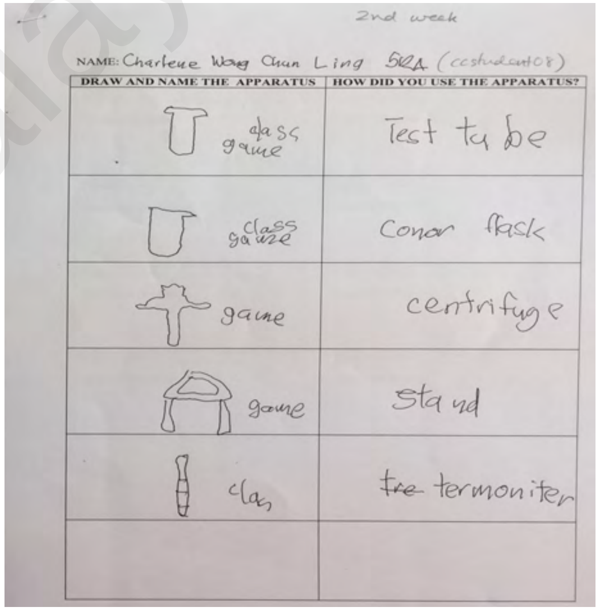
Student DE11

Test tube, beaker



Student DE5

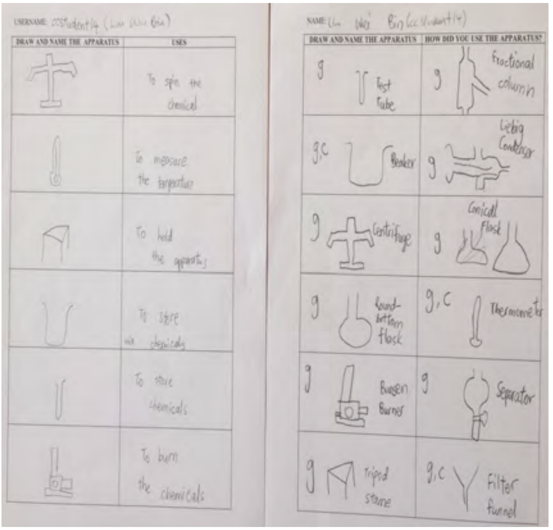
Test tube, beaker



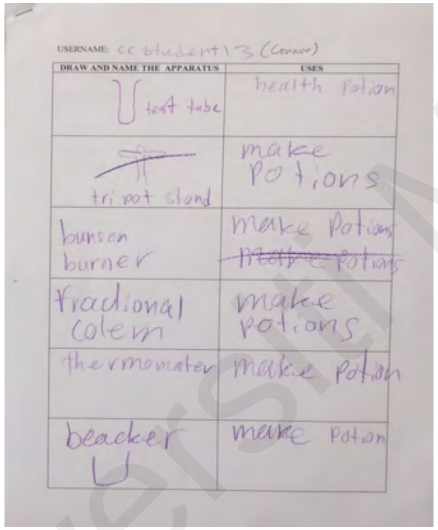
Student DE8

Test tube, conor flask, centrifuge, stand, termonitor

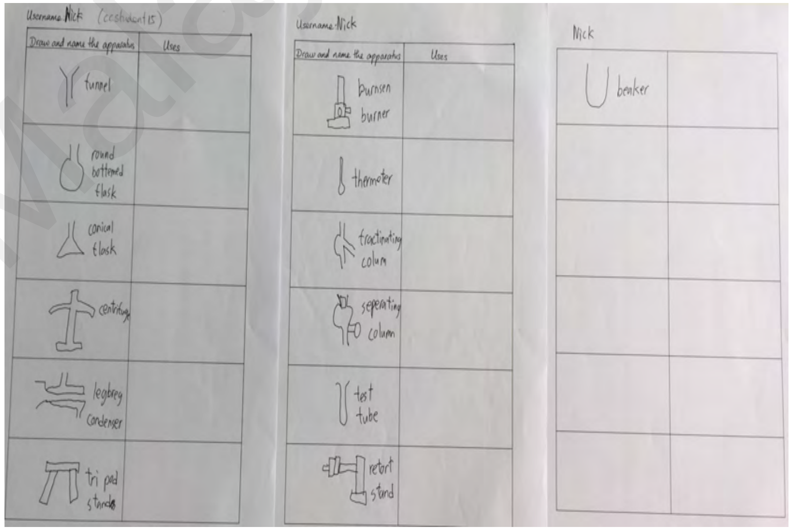
Apparatus drawings by three twelve year old students



Student DE14



Student DE13



Student DE15

Test tube, beaker, centrifuge, round-bottom flask, Bunsen burner, tripod stand, fractional column, Liebig condenser, conical flask, thermometer, separator, filter funnel

Test tube, tripot stand, Bunsen burner, fractional colem, thermometer beacker

Funnel, round bottomed flask, conical flask, centrifuge, leybreg condenser, tripod stand, bunsen burner, thermoter, fractinating colum, seperating column, test tube, retort stand, beaker

Figure 5.14: Comparison of apparatus drawing for all three age groups.

The findings of knowledge attainment on crafting potions across age were similar with two students, one aged ten and the other aged twelve listing in detail the colours of each potion, almost all their exact names and apparatus used as shown in Table 5.5. They could even name and describe some of the physical separation techniques needed to craft the potions. An excerpt of conversation between the researcher and students regarding crafting potions are as follows:

DE15: *"There is the red color health potion, the blue color speed potion, the green color accuracy potion, the yellow color defense potion and the purple color damage potion."*

DE7: *"I know for the health potion there is the trifling cordial the middling cordial and the rejuvenating, and then the…"*

DE15: *"Then for the damage one, there's the Herculant brew, behemoth brew and the dominating brew."*

(Focus Group Interviews: 9 Nov., 2017)

It is indeed amazing to hear students between ten and twelve year old being able to name the various potions in the game, list the items needed to craft the required potion and even identify the particular physical separation technique required. Again, it must be noted that no formal teaching was conducted and the research study duration was only two weeks.

Table 5.5

Crafting potions list as provided by students during the second focus group interview

Colour/ Use of Potion	Potion Name	Items/Apparatus Used	Physical separation techniques
Red/ Health	Trifling cordial Middling cordial Rejuvenating cordial	eal fruit, test tube, centrifuge	Centrifugation

Table 5.5, continued

Blue/ Speed	Bling bling draft	Conical flask, separating funnel, retort stand	Separation
Green/ Accuracy	Hocus pocus	Everything from damage potion except fractionating column	Distillation
Yellow/ Defense,		Filter funnel, filter paper and conical flask,	Filtration
Purple/ Damage	Herculant brew, Behemoth brew Dominating brew	Round bottom flask, Conical flask, thermometer, fractionating column, tripod stand, Liebig condenser, Bunsen burner	Fractional distillation

Based on the online interactive quiz results shown Table 5.1, two ten year old students scored 100% as compared to only one eleven year old who scored 100% while three twelve year olds scored between 93% – 97.9%. These results showed the younger aged students were able to attain Chemistry knowledge as well as their older peers. Results from focus group interviews showed similar findings with one ten year old boy being able to give comprehensive answers such as:

Researcher: *"Do you know the types of bonds that we have in ChemCaper?"*

DE7: *"Covabon, iobon and metabon."*

Researcher: *"Can you list down the petticles that require Covabon?"*

DE7: *"Cryo, Oxyto, Flowyn, Hizo, Brom-Brom."*

(Focus Group Interviews: 9 Nov., 2017)

This ten year old boy could also give detailed answers to petticle requiring iobon and metabon. In addition, he could also describe the process of electron transfer in ionic bonding and electron sharing in covalent bonding. These descriptions are discussed in the next section.

5.4.3 Head Fake

Findings from the above sections revealed that the amount of Chemistry knowledge attained (meaningful learning) from the game by the selected iGeneration students depended on the activities they participated in at different levels of the game and their ability to construct knowledge through play and discovery as they actively seek to solve problems faced in the game. For example, one boy, named student DE13 decided not to waste his time tracing apparatus and crafting potions. Instead, he achieved his objectives of playing the game and leveling up by fighting alycons to get money to buy the petticles he wanted. Hence, without applying repetitive skills of tracing apparatus, he was unable to remember names of apparatus. Moreover, his knowledge of crafting potions was also lacking, again due to the lack of repetitive skills. Although he managed to master the game through the purchase of petticles, this strategy compromised on his Chemistry knowledge. So, he missed learning the Chemistry content in the game and by the end of the first week, he realized he did not learn much of Chemistry. He was not able to draw most of the apparatus used, nor was he able to explain how to craft potions or the type of bonds different petticles have during the focus group interview. In the second week, student DE13 made more attempts to use repetitive skills of tracing, crafting and bonding instead of trading thus making progress in apparatus drawing as shown in Figure 5.15.

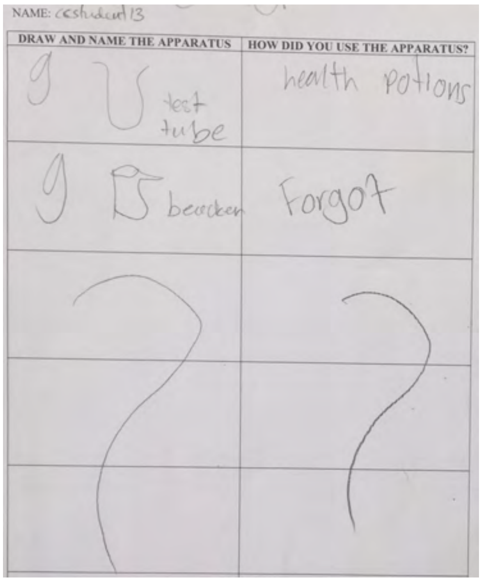
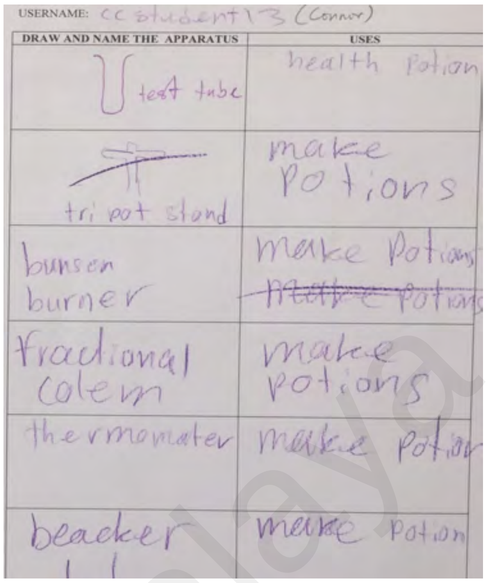
First week	Second week
	
<u>Description:</u> Test tube- health potion. Beaker - forgot.	<u>Description:</u> Test tube, Tripot stand, Bunsen burner Thermometer, Beaker – all used to make potions

Figure 5.15: First week and second week apparatus drawings by student DE13.

Other examples of repetitive skills employed by students to draw apparatus, craft potions and bond petticles in order to level up and master the game have been discussed under Chemistry knowledge attained in page 119 to page 121.

The researcher also found that when students employed strategizing skills such as synchronizing their game (as discussed under active participation in page 108), not only their motivation increased, this social inclusion helped them to learn better as they support each other in battle strategies and game play.

Another notable reinvention is that the attainment of Chemistry knowledge using ChemCaper did not follow a linear approach as opposed to the traditional method of learning Chemistry. For example, in the Chemistry curriculum, students would normally need to learn about atomic structure before proceeding to Chemical bonds but in ChemCaper, learning was random, situational and based on the needs as well as experience of the player. For instance, players only learn about Chemical bonding when they want to make petticles to battle alycons. However, as different petticles are made from different types of Chemical bond, players might encounter learning only a certain type of bond first and eventually learn other type of bonds as the need arises.

All the above findings also point to the fact that many students were so engrossed in mastering the game, they were not aware that they were learning Chemistry, which are discussed further in the next section.

5.4.4 Implicit to Explicit Learning

The researcher found that situated learning occurred when these students were actively engaged with the game throughout the study period (discussed in Chapter 3, Conceptualization of the study). Results from detailed probing during focus group interviews revealed that students were able to convert what they played in the game into Chemistry knowledge. For example, initial responses received included:

> *"We get to bond petticles and defeat bosses; we can fight and make many potions; it is interesting to find more ways to create different petticles; the best thing is that you can make your own strategies on how to defeat the monsters and can learn Chemistry at the same time"*.
>
> (Focus Group Interviews: 9 Nov., 2017)

When probed further on what it meant by "can learn Chemistry at the same time", student DE15 responded, *"I learned about some of the elements, I learned what would happen if you combine certain things, I learned what are three types of combining elements are called, and I learned how to draw the apparatus properly".*

(Focus Group Interviews: 9 Nov., 2017)

Another example of meaningful learning and converting implicit to explicit learning was when students exclaimed many of them loved cryo because of its ability to freeze the opponent but student DE7 added,

"Cryo freeze because nitrogen is actually damn, damn cold, it's really cold."

(Focus Group Interviews: 9 Nov., 2017)

Through discovery learning, student DE7 gave a very detailed answer that showed an in-depth level of critical thinking as he explained,

"Like normally I classify particles into three groups, the ones found in Camp Ungku, Reacta and Sub-Rosa. The reason I like Cryos in Camp Ungku is because Oxyto does too less damage, and potassium is more for healing. When Brom Brom comes in, I like Brom Brom as well because of his like taking damage for the vaporizing bomb".

(Focus Group Interviews: 9 Nov., 2017)

Due to the limitation of time, the researcher could not obtain more information but have to move on with other questions. When the researcher asked if they have ever observed what happens during the formation of Covabon, responses from the first focus group were vague and required prompting:

DE18: *"The balls."*
DE14: *"Electrons."*
Researcher: *"Yes, continue.."*
DE14: *"The electrons, in the middle you have 6."*
Researcher: *"Good, 6 is for which petticle?"*
ALL: *"Cryo! Cryo!"*

(Focus Group Interviews: 10 Nov., 2017)

Answers from the second focus group interview for the formation of covalent bonds was more detailed and are as the following:

Researcher: *"What did you observe when you made Covabon?"*
DE7: *"OK so let's say we are doing Flowyn, so this are the Fluorine orbs, they actually share electrons, like because one Fluorine orb has seven outer electrons so the other one must have the same."*
Researcher: *"Okay…."*
DE7: *"So, there will be like two here, two here, two here and one here. Same for the other one... But then since they both have one on this side, they will combine and form two two two two two two two."*

(Focus Group Interviews: 10 Nov., 2017)

The above description was accompanied by hand gestures to show he knew exactly what he was describing. Another student who also showed exceptional explicit learning was DE15 as he assisted DE 7 in describing the formation of Hizo:

DE15: *"Hizo is the only Covabon which has three orbs."*
DE7: *"Yes so, like the hydrogen orb will be here, the another hydrogen orb will be here, and the oxygen orb will be on top."*
DE15: *"So around the oxygen orb there's actually two two one one, but then the hydrogen orb contributes the extra one, so now its two two two two."*

(Focus Group Interviews: 9 Nov., 2017)

Their descriptions on the formation of Cryo, which is nitrogen molecules were also accurate and listed as follows:

Researcher: *"What's the observation for Cryo?"*
DE15: *"About the same as Flowyn."*
Researcher: *"But how many electrons does it have?"*
DE7: *"Five each, so there's like two Cryos, and there's one here one here, and then there's like six here, three belongs to this one and three belongs to this on."(hand gestures included).*

(Focus Group Interviews: 9 Nov., 2017)

In addition, the following excerpt showed these two students were able to describe the difference between covalent bond and ionic bond:

Researcher: *"So, what is Covabon about?"*
DE7 and DE15: *"Sharing!"*
Researcher: *"That's right, that's correct. What about Iobon? Was there any sharing?"*
DE15: *"No, it's more of giving and taking."*
Researcher: *"Good! Who gave?"*
DE7: *"The metals."*
Researcher: *"And who took?"*
DE15: The gases"

(Focus Group Interviews: 9 Nov., 2017)

Responses for the formation of Sal-T and Lymlyte using ionic bonds also drew an interesting conversation as shown below:

DE13: *"The calcium orb and the sodium orb, the electrons goes to the other orb."*
Researcher: *"So, the electrons from calcium and sodium orb flies to?"*
DE13: *"Oxygen and chlorine."*

(Focus Group Interviews: 10 Nov., 2017)

However, students who showed weaker attainment of Chemistry knowledge were unable to provide an explanation as illustrated in the conversation below:

Researcher: *"That's interesting. Do you know why that happens?"*
DE18: *"No. Because the electrons think they are too few and they have too much, so they go and join them."*
Researcher: *"Would you like to know the answer?"*
DE12: *"One is negative and one is positive, they join together"*
DE13: *"To get neutral."*

(Focus Group Interviews: 10 Nov., 2017)

For the second focus group, students who had stronger attainment of Chemistry knowledge gave accurate and interesting descriptions on the formation of sodium chloride and calcium oxide. The following is an excerpt:

Researcher: *"Can you list down petticles that require Iobon?"*
DE15: *"Sal-T and Lymlyte."*
Researcher: *"Next, have you observed what actually happens during the bonding of these petticles?"*
DE7: *"Yeah."*
DE15: *"Yeah I saw it."*

(Focus Group Interviews: 9 Nov., 2017)

The following is a detailed explanation of formation of Sal-T, which is salt by students DE7 and DE15:

DE7: *"Let's say I'm bonding a Sal-T and so the sodium orb and the chlorine orb would appear, and then the sodium orb has one electron and the chlorine orb has seven electrons, okay, and in the middle of the process."*
DE15: *There'll be sparks and lightning, and the one electron from the sodium would transfer to the seven electrons of the chlorine, and then they make Sal-T. I don't know where and for some reason, Sal-T can climb out from the Petcubator."*

(Focus Group Interviews: 9 Nov., 2017)

Their detailed explanation showed explicit understanding on the formation of ionic bonds, which could only be explained that implicit learning had been converted to explicit learning from playing ChemCaper as these students have not been formally exposed to Chemistry learning, especially on bond formation. Explanation for the formation of Lymlyte, which is Calcium oxide displayed similar higher order thinking skills.

However, their explanations for the formation of metallic bond were more vague, possibly due to the fact that electrons were not transferred or shared during the formation of metallic bonds. According to the students, the type of petticle obtained depended on whether there would be one, two or three free electrons surrounding the orb. Below were excerpts of conversation:

DE15: *"Depends on the level you get."*
DE7: *"If it's Bitty, there'll only be one orb and there'll be one electron surrounding it."*
DE15: *"If it's Ptassyum, Sodi-U, or Lith, there'll be one, if it's Elycium or Magnuss, there'll be two."*
DE7: *"For Mitties, there'll be two orbs, and then there will be the same number of electrons depending on the petticle.*
DE15: *"Gritty follows the same trend, three, three orbs. So the metabons are the only petticles where you can tell their level before you get them."*

(Focus Group Interviews: 9 Nov., 2017)

The interviews have given depth as to how each individual respondent process the information they received from the game and translate what they learnt from the game to what they understand about Chemistry. They have no notion that crafting potions are actually conducting physical separation techniques that they attained from the game. What is more astounding is to listen to kids, aged between ten to twelve, who have not been introduced to formal Chemistry explaining about electron sharing in covalent bonds, electron transfer in ionic bonds and electrons just moving around the atoms in metallic bonds to make petticles consisting of either one, two or three atoms. To these kids, they are explaining what they observed during petticle bonding but to the Chemist, these kids have just explained what actually occurred to atoms during Chemical bonding, which is abstract and difficult, even for older students to understand (Dahindsa & Treagust, 2009; Kind & Kind, 2011).

Although much research have been done on teaching in the 21st century, our local classrooms remain firmly established in what is commonly known as the

‘Factory Model’, which was designed for the Industrial Revolution, although one may argue that it is better equipped with LCD projectors, air-conditioning and other cool gadgets. Educators need to have a change in their mindsets and practices to accommodate the shift in learning styles among the iGeneration students and make full use of the technology incorporated in schools for students to optimize their learning experiences in the ways they love most, which is digital games.

5.5 The Importance of Scaffolding for the Selected iGeneration Students

With the addition of this emergent research objective, the researcher was able to bridge the gap found in the pilot study, that showed students lacked direction, attained minimal Chemistry knowledge and were unable to convert implicit learning to explicit learning show without sufficient scaffolding. Hence, the findings in the following sections were able to explore the importance of scaffolding for the selected iGeneration students.

5.5.1 Motivator

In the actual study, the presence of Teacher J and Teacher MJ shown in Figure 5.16, helped many student become motivated to play the game as they dispensed advice and pointers on what to do especially on defeating the sea beast bob in Camp Ungku (level one) in order to enter ReacTa (level two). Besides that, allowing face-to-face interaction allowed students that were more knowledgeable work together with their peers. These students became the MKO for their peers as discussed earlier under describing the reinvention of Chemistry learning. These seem to point to the benefit of having students’ cooperation and collaboration that is called for in Vygotsky’s social cognition theory.

5.5.2 Scaffold

Observations from the video recordings also showed students felt confident when they received assistance and guidance, especially when they first started the game and was unsure how to navigate. For example, a few students (DE2, DE3, DE4, DE5, DE6, DE8, DE9, DE10 and DE18) had many questions as they played the game and needed assistance on physical separation techniques when crafting potions. Teachers and the researcher noted that when crafting damage potion, they needed assistance on the correct use of the Bunsen burner and Liebig condenser. Hence, teachers took the opportunity to explain how the hole in the Bunsen burner affected the colour and temperature of the flame. Another point that students learnt was to pour the potions carefully into the two test tubes before centrifugation when crafting health potions. Initially, many spilled the liquid out but when they learnt from teachers J and MJ that how they handled the apparatus affected the percentage of purity and number of portions they obtained, they were determined to try and try again until they got 100% pure potions that were powerful.

Teachers today must be equipped with technological-pedagogical content knowledge (TPACK) and that their roles should evolve to become not only motivators, illuminators and mentors, but also knowledge provider and effective facilitators to provide proper scaffolding to support students' development as posited by Hattie (2009), Marzano, Pickering and Pollock (2001), Sousa and Tomlinson, (2011).

5.5.3 More Knowledgeable Other (MKO)

Having face-to-face interactions among students and with teachers when students played the game actually helped in the conversion of implicit learning to explicit ones. For example, one student asked teacher MJ why the balls were flying around during bond formation. The explanation provided by teacher MJ helped the student understand his observations and distinguish between what happens during ionic bonding and covalent bonding. Another example was the opportunity to explain how the hole in the Bunsen burner affected the colour and temperature of the flame during the crafting of potions. There are many more instances like these where students actually benefitted with the presence of a MKO to explain the Chemistry content.

Figure 5.16: Teachers' presence was crucial to support students' learning in the class.

According to their Science teacher, play and discovery learning was made more meaningful when students were allowed to play together. The presence of peers who grasped the game faster is also important to those who are new to the chemistry world. These peers would be the MKO that provide the additional motivation and knowledge as they got together in groups teaching and discussing the mechanics of the game and what they observed during game play when they meet in school. In fact, results from the online quiz showed the attainment of Chemistry knowledge was very high in all three sections of Chemistry learning in just a short span of two weeks.

Consequently, the researcher discovered that the instructional guidebook called the ChemCaper Chempendium (Appendix N) given to students at the end of the first week also acted as a scaffold. It was discussed under evaluating Chemistry learning that students became more aware of the Chemistry content in the game and their knowledge increased markedly when they used the guidebook as their point of reference throughout the second week. It was interesting to note that although the same information and more is available in the game, students preferred the physical book as reference while playing. Figure 5.8 shows two distinct examples comparing the first week and the second week answers of a student who drew and name apparatus. By the end of the second week, many students could also classify the petticles based on their type of bonds as well as name some of the physical separation techniques they used to craft potions.

From the Literature Review in Chapter 2, it was stated that the roles of teachers must evolve to prepare students with 21st century educational skills. The findings above support the call for teachers today to become motivators, illuminators, mentors and effective facilitators to provide proper scaffolding to support students' development (Hattie, 2009; Marzano, Pickering, & Pollock, 2001; Sousa & Tomlinson, 2011). The need for an MKO to advance the learning of students have also been evidenced by Squire et al. (2004) as discussed in the theories behind digital game based learning in chapter two. This study went one step further to show that besides teachers, peers also acted as MKO. For example, student DE7 was clearly the mentor for student DE8 (shown in Figure 5.5), providing her with motivation and helping her to play and understand the game better. In fact, the researcher noted in her journal that when student DE7 was absent, student DE8 looked sad and demotivated.

In conclusion, findings from the above sections further evidenced that it is imperative to have the teacher as facilitator to be a guide, mentor, motivator and MKO to show students how to play the game well and advise them how to interact best with the game, besides providing them explanations to convert implicit learning to explicit ones. The Chempendium book given to students in the actual study also became their referral point as the attractive visuals provided them information needed to play the game.

5.6 Chapter Summary

This chapter presented the findings of the actual study and the ensuing discussions to answer the research questions. The research questions focused on how this game could reinvent the learning of Chemistry among iGeneration students who have not been formally introduced to Chemistry learning. The motivation of the students was implored and how the reinvention of Chemistry occurred was discussed in detail. Besides that, a suitable interactive online assessment was created to evaluate the attainment of Chemistry knowledge. Finally, the importance of scaffolding was also investigated in this study.

The motivation of students with regards to playing ChemCaper, the selected DRPG were investigated, as this component of the study is imperative to ensure that the game would be able to provide students with immersive environment to keep them attentive and motivated to learn, which is one of the problems faced by educators (Devlin, Feldhaus & Bentrem, 2013; Howe & Strauss, 2000; Levin & Arafeh, 2002; Prensky, 2001b; Raman & Abdul Halim, 2013; Samuel & Zaitun, 2007; Stofflett, 1998; Woempner, 2007; Zoller, 2000).

For the second research question, a suitable online interactive quiz was necessary to assess the Chemistry knowledge attained by the selected iGeneration students after playing ChemCaper. Observations from the pilot study (discussed in Chapter Four) provided substantial evidence for the researcher to modify the platform used to administer the online interactive quiz from Kahoot to Google to provide more privacy and also to ensure that the questions do not provide immediate answers that might cause students to lose confidence. In addition, the question formats were also modified to the right cognitive level of the selected iGeneration students as well as provide more relevance to the game.

For the evaluation of Chemistry knowledge attained by the selected iGeneration students, it was found that the routine practice of tracing apparatus and crafting potions led to them being familiar with the apparatus they used and the physical separation techniques they conducted. In addition, the frequent bonding of petticles also led to the students learning about the types of chemical bonds available. In other words, the continuous mastery of game-play allowed students to translate implicit learning to explicit learning. Written assessments collected from the second week focus group interviews showed a marked increase in Chemistry knowledge attained by the selected iGeneration students, especially in tracing apparatus. These findings are supported by the online quiz results (Appendix U), which showed students scoring very well in all three sections, which were identifying apparatus, physical separation techniques and types of Chemical bonds. Results also showed that in the first week, students were doing associative learning such as identifying colour or location of the buttons when choosing types of bonds, but in the second week, they were made aware that the colour or location of the certain button means they were choosing a certain bond.

The reinvention of Chemistry learning among the selected iGeneration can be seen when these students who have not been exposed to formal Chemistry learning were able to grasp the concept of Chemical bonding. The detailed explanation of Chemical bonding provided showed their understanding of Chemistry learnt was mainly from playing a digital game as no formal teaching were conducted. It also showed that learning was not linear and based on skills as students who were ten years old could fare as well as their older peers. Again results from written assessments and the online interactive assessment provided support to these statements. The concept of head fake is interesting to explain the reinvention of Chemistry learning as students were informed that they would be participating in a DRPG but were actually participating in a research study on Chemistry learning.

Finally, observations made by the researcher through video recordings and journaling as well as from the students' Science teacher showed the importance of face-to-face interactions among students. Findings showed that peers acted as the MKO but the presence of a teacher as a mentor, motivator, knowledge provider and catalyst for students to have meaningful learning while they play is the most important. It was interesting to also note that the instructional guidebook also acted as a form of scaffold to the selected iGeneration students.

In the next chapter, summary of the findings, implications of the study and the conclusion of the study will be discussed.

CHAPTER 6

SUMMARY, IMPLICATIONS AND CONCLUSION

6.1 Introduction

The summary of the research findings in this study and its implications are presented in this chapter. The contributions towards existing literature and recommendations for future studies are also discussed. Finally, this chapter will close with a conclusion of the study.

6.2 Summary of Research Findings

6.2.1 Motivation

This study was able to show that ChemCaper could capture the motivation of the selected students as results showed participants gave their complete focus and attention to the game. Students interacted with the game, their friends and teachers throughout the research period and video analysis showed not a single moment of boredom existed. Findings also showed the game was able to provide students with a sense of achievement, as the continuous cycle of searching for items to complete quest, battling monsters to get rewards and leveling up to get more ‘cool’ petticles provided the ‘flow’ and immersion to keep students motivated (Harackiewicz et al., 1997).

Discussions in Chapter 2, literature review states that the perception of Chemistry being difficult often repels many (Aikenhead, 2003; Gabel, 1999; Johnstone, 1991; Kozma & Russel, 1997), but this study found that ChemCaper actually created a positive attitude and interest towards learning Chemistry. This positive attitude among the iGeneration students (who are all well below the age of learning Chemistry formally) provided them the motivation and allowed them to experience learning Chemistry while having fun. This game also helped foster stronger bonds as students cooperated and collaborated with each other to battle the monsters and learn Chemistry along the way. Students were highly motivated and interest as well as motivation stretched beyond game time as discussions continued along the corridors and in other places during school hours. Figure 6.1 shows a summary of motivation of participants from playing ChemCaper.

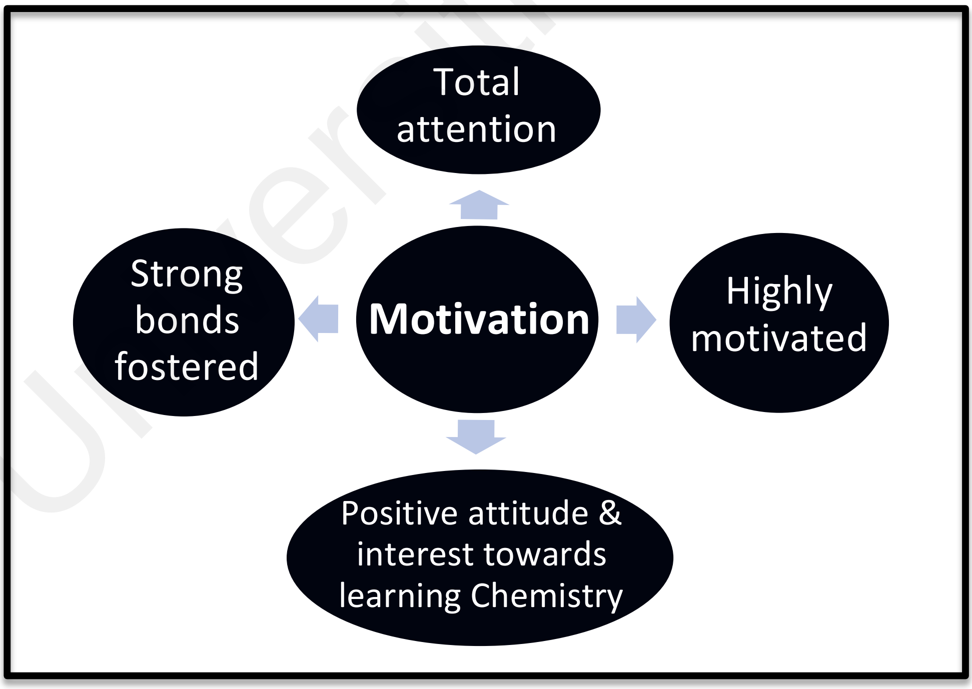


Figure 6.1: Summary of motivation towards playing ChemCaper

6.2.2 Chemistry Knowledge Attained

The data collected became more meaningful when initial findings from the pilot study showed the need to modify the online quiz assessment and data collection method. These modifications helped to make the study more successful in understanding and evaluating the reinvention of Chemistry that occurred from this game. The effects are manifold, for instance, the online interactive quiz using Kahoot was modified to using Google as the platform as it provided more privacy and was less intimidating. Besides that, quiz items were modified to relate to the game content and Chemistry words that were too difficult for young learners to comprehend were removed to help make the evaluation valid and reliable.

From the findings discussed in the pervious chapter, most students from the actual study were able to draw more that 60% of all the apparatus that they traced from the game in a short span of two weeks. In addition, many were able to verbally explain a few physical separation techniques that they also learnt from the game. Although literature review mentions that connecting the macroscopic and microscopic levels of thought is a significant challenge to novices (Bradley & Brand, 1985; Johnstone, 1974). However, participants from the research study could explain briefly what happened to the electrons during ionic bonding and covalent bonding. Two students who were more observant and analytical could even provide detailed descriptions on Chemical bonding, that the researcher felt even some Form Four students (sixteen year olds) have difficulty explaining. It is noteworthy to mention that these students had no prior help from teachers or parents about Chemistry.

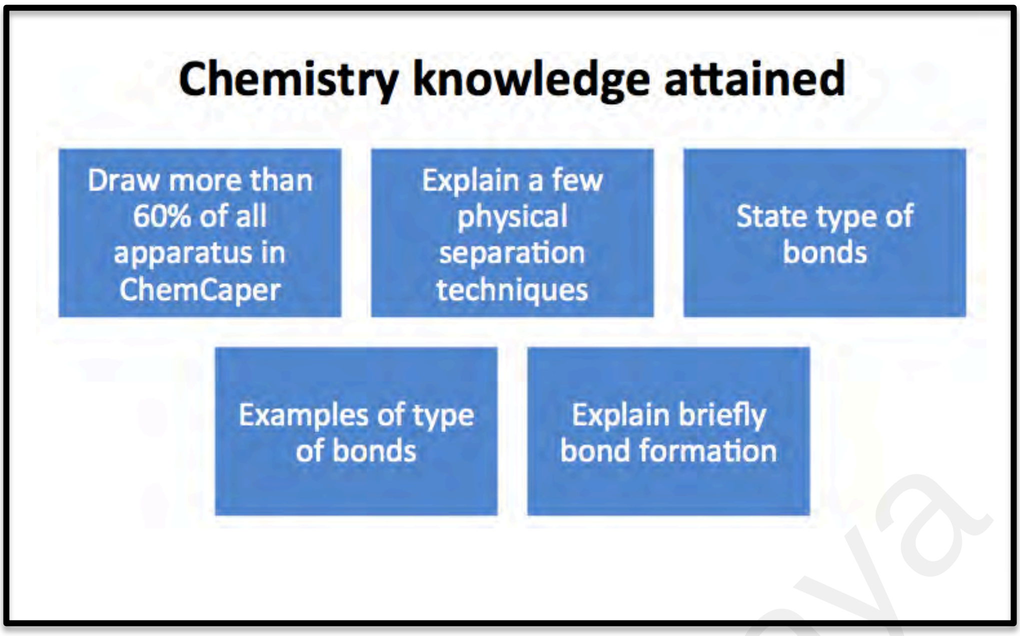


Figure 6.2: Summary of Chemistry knowledge attained.

6.2.3 Importance of Scaffolding

The Chemistry learning experienced by students is optimized when scaffolding is provided for students along their ZPD. These scaffolding came in many forms, including the Chempendium embedded in the game, the instructional guidebook provided in the second week, peers who grasp the game faster and also teachers who were at hand to provide the necessary guidance. It was discovered that those who grasped the game faster were teaching and discussing the mechanics of the game with peers who needed help. This provided the necessary scaffolding for some students along their ZPD.

Another element found in the game was associative thinking. Students' ability to do associative thinking were frequently observed during the focus group interviews, whereby students described they chose the correct bonding to make petticles based on colour or position of the bond button. The reason for associative thinking is because the game design provides students with visuals of how bonding occurs in atoms with minute details such as colour and characteristic of petticles embedded in the game. For example, the colour and number of rings around the orbs actually match the colour and number of electron filled shells of the actual element. Another example of implicit characteristic that matches what the student will eventually learn in Chemistry is nitrogen, which is named Cryo because it defeats opponents by freezing. Hence, nitrogen is associated with cryogenics. Again, a facilitator is crucial to guide this associative thinking and translate it to constructive thinking. This shows the importance of an educator to provide the necessary scaffolding for students to maximize their learning. Figure 6.3 illustrates the summary of scaffolds in ChemCaper.

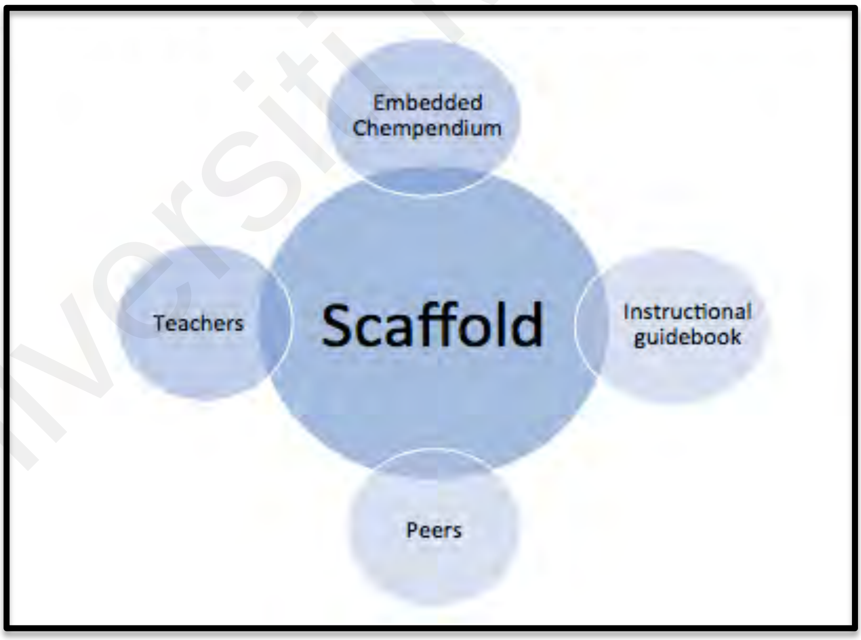


Figure 6.3: Summary of the importance of scaffolds in ChemCaper

6.2.4 Reinvention of Chemistry Learning

The findings of this study also support advocators of DGBL that ChemCaper allowed children to explore, discover and create meaningful play through what is known as situated learning. One element inserted into the game to allow situated learning is head fake, whereby learning occurs without students' realization as they thought they were mastering the game. The implicit learning that occurred through head fake becomes expressed explicitly when teachers step in to facilitate the learning process, providing the scaffolding as they explain to students the Chemistry content that they have experienced.

Another element that helps with memory retention is active learning. The game provides stimulation for all three visual, auditory and kinesthetic senses as students actively learn how to problem solve through game strategy. Two students actually did an analysis of the best strategy to defeat the boss for each level. All these information are imprinted in the students' mind and helps in memory retention when students are exposed to Chemistry learning in their later years. This is especially important as Chemistry is considered an abstract subject. Finally, the repetitive nature of the game, which requires constant practice to trace apparatus, craft potions and choose the correct bond to make petticles leads to mastery learning.

All these elements when incorporated into a DRPG leads to non-linear learning that is not age based but more skills based. Besides that, students that have not been formally introduced to Chemistry are able to draw apparatus which are not in their Science curriculum, identify the types of physical separation techniques and have an understanding of the types of Chemical bonds required to produce different type of petticles. The reinvention of Chemistry becomes even more real when learning is not age based but skill based as findings show ten year olds have equal if not better knowledge of Chemistry compared to their older peers. Besides that, ChemCaper has also allowed students to develop 21st century skills set like creativity skills, problem solving skills, having initiative and self-direction and communication and collaboration skills.

Finally, findings show that although ChemCaper is completely learner centred. However, it must be teacher facilitated in order for students to translate implicit learning to explicit learning and obtain the right learning content and process. It must also be impressed upon that a game is just a game that may be able to maintain the interest and motivation of students. However, teachers still play a crucial role in facilitating the learning process especially in the reinvention of difficult subjects like Chemistry. The reinvention of Chemistry learning that occurred is summarized in Figure 6.4.

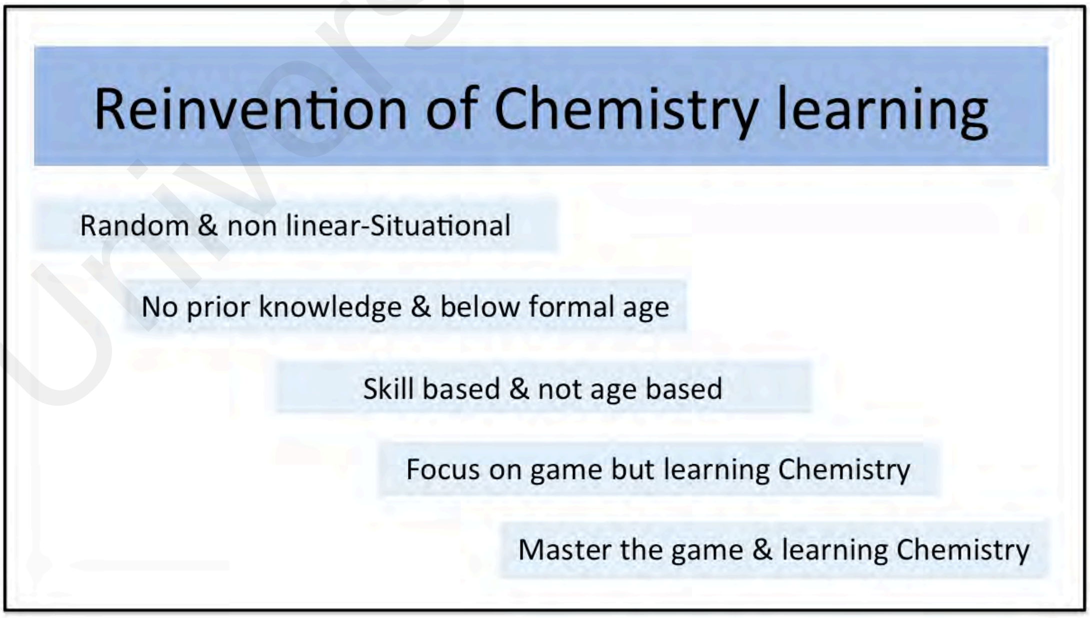


Figure 6.4: Summary of the reinvention of Chemistry that occurred from Chemcaper

6.3 Implications of the Study

Based on findings from the current study, there are a few implications for the Malaysian Education Curriculum. This study shows that students are very interested and motivated when learning using digital games. Hence, teachers and educators might consider altering their teaching styles with their TPACK knowledge to suit the learning styles of the iGeneration. Moreover, if educational digital games are designed and incorporated into the education curriculum, parents should no longer be apprehensive to allow their children to play digital games, with adult supervision.

Results showed that students were able to learn Chemistry from playing digital games. Hence, this study would prove to be a stepping-stone for more studies on how ChemCaper can be incorporated in the Chemistry curriculum specifically and how digital games, like DRPG can be incorporated in other curriculum in general.

Most importantly, the findings of this study have shown that it may be possible to introduce Chemistry to children that are younger and that education should no longer be age based but based on skills.

6.4 Future Research and Recommendations

It is evident that digital technologies will eventually play a vital role in shaping the lives of our future generation and this includes the future of the education system. Although substantial budget have been allocated and spent on equipping classrooms with connectivity and digital technologies (Malaysia Education Blueprint 2013-2025, 2013), results showed students fared poorly in science in national examinations (Boo, 2015).

In this research study, findings showed that the motivation of students to learn Chemistry was developed through playing ChemCaper. The researcher also discovered that as students immersed themselves in a virtual world of imagination, they attained Chemistry knowledge from the game. Hence, this game might be able to bridge the gap and draw students back to being interested and motivated in Chemistry and perhaps other Sciences. In addition, this game might also prove to be effective in learning Chemistry. Hence, an intervention study might help to establish the effectiveness of this game. In addition, as the sample size in this study was only twenty, the researcher would recommend a larger sample size to include more schools and states in Malaysia for future studies if budget permits. This will provide statistical significance and power to the current study. Another aspect that can be included in future research is to study the effectiveness of embedding digital games like ChemCaper into the Science curriculum of selected schools to merge game-play with education, especially in the age of the iGeneration.

Future studies might also consider looking at evaluating how students are able to acquire Chemistry knowledge from playing this game. In other words, an in-depth study on the students' cognitive processes that resulted in learning Chemistry from this game would help understand better how to reinvent the learning of Chemistry and perhaps other subjects too. One component that might be of consideration is to include evaluating how non-linear learning can occur among students through game-play and also to investigate in more detail how students through their cognitive processes can progress based on skills and ability.

6.5 Conclusion

From the findings of this study, it can be concluded that digital game based learning like ChemCaper shows promise for the future of education. The reinvention of Chemistry learning using ChemCaper takes a different approach in numerous ways. First, the study showed that prior knowledge is not required to learn Chemistry using ChemCaper. This means development does not precede learning. Hence, results showed students below the age of formal learning can attain the same knowledge as compared to peers 4 to 6 years older. Second, the game is able to maintain students' motivation to learn Chemistry as they enjoyed playing the game. The study also showed students learnt from implicit learning or head fake while enjoying playing ChemCaper as opposed to didactic pedagogy. Third, learning takes a non-linear approach, as learning becomes random and situational. It is not structured and does not follow a methodological sequence because students choose to learn what they want based on their preference and the situation they encountered in the game. Fourth, Chemistry learning can occur across age, based on skills as students who were more competent in the game progressed faster than their peers.

Indeed, this game have shown that it is possible to have a commercial digital role play game that have sound pedagogical tools that can attract the masses. But, findings from this research study also showed that the role of a teacher as facilitator is still crucial in ensuring the success of learning among the students.

REFERENCES

Ahn, J. H. (2008). Application of the experiential learning cycle in learning from a business simulation game. *E-Learning, 5*(2), 146–156.

Aikenhead, G. S. (2003), Chemistry and physics instruction: Integration, ideologies, and choices. *Chemical Education: Research and Practice, 4*(2), 115-130.

Alexander, P. A., & Jetton, T. L. (1996). The role of importance and interest in the processing of text. *Educational Psychology Review, 8*(1), 89-121.

American Association for the Advancement of Science (1989). Science For All Americans: A Project 2061 Report on Literacy Goals in Science, Mathematics and Technology. Washington, DC.

American Association of Colleges for Teacher Education (2010). 21st century knowledge and skills in education preparation. Retrieved from https://files.eric.ed.gov/fulltext/ED519336.pdf

Ash, K. (2011, March 14). Digital gaming goes academic. *Education Week, 30* (25), 24–28. Retrieved from http://www.edweek.org/ew/articles/2011/03/17/25gaming.h30.html?tkn=XQDCbAEm%2BOYlXmj8CrgGehhpjbVOReeJEqon

Avargil, S., Herscovitz, O., & Dori, Y. J. (2012). Teaching thinking skills in context-based learning: teachers' challenges and assessment knowledge. *Journal of Science Education and Technology, 21*, 207–225.

Ayas, A., & Demirbas, A. (1997). Turkish secondary students' conceptions of the introductory concepts. *Journal of Chemical Education, 74*(5), 518.

Baker, R. S. J. D., & Yacef, K., (2009). The state of educational data mining in 2009: A review and future visions. *Journal of Educational Data Mining 1*(1), 3–17.

Barab, S. A., Arici, A., & Jackson, C. (2005). Eat your vegetables and do your homework: A design based investigation of enjoyment and meaning in learning. *Educational Technology, 45*(1), 15–20.

Barab, S. A., Scott, B., Siyahhan, S., Goldstone, R., Ingram-Goble, A., Zuiker, S., et al. (2009). Transformational play as a curricular scaffold: using videogames to support science education. *Journal of Science Education and Technology, 18*(4), 305–320.

Barclays (2013). A summary of talking about my generation: Exploring the benefits engagement challenge. London, UK: Author. Retrieved from https://wealth.barclays.com/content/dam/bwpublic/global/documents/global-stock-rewards/multi-generations-summary.pdf

Barko, T., & Sadler, T. D. (2013). Practicality in virtuality: finding student meaning in video game education. *Journal of Science Education and Technology*, *22*(2), 124–132.

Batchelor, J. (January 31, 2018). Games industry generated $108.4bn in revenues in 2017. Gamesindustry.biz. Retrieved from https://www.gamesindustry.biz/articles/2018-01-31-games-industry-generated-usd108-4bn-in-revenues-in-2017

Baxter, J., & Eyles, J. (1997). Evaluating qualitative research in social geography: Establishing 'rigour' in interview analysis. *Transactions of the Institute of British Geographers*, *22*(4), 505-525.

Beckett, K. (2013) Professional wellbeing and caring: Exploring a complex relationship. *British Journal of Nursing*, 22 (19). pp. 1118-24. ISSN 0966-0461 Available from: http://eprints.uwe.ac.uk/22483

Behrens, J. T., Frezzo, D. C., Mislevy, R. J., Kroopnick, M., & Wise, D. (2007). Structural, functional, and semiotic symmetries in simulation-based games and assessments. In E. L. Baker, J. Dickieson, W. Wulfeck, & H. F. O'Neil (Eds.) *Assessment of Problem Solving Using Simulations* (pp. 59–80). New York: Erlbaum.

Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., & Berta, R. (2013). Assessment in and of serious games: an overview. *Advances in Human-Computer Interaction, 2013*, 1.

Ben-Zvi, R., Eylon, B., & Silberstein, J. (1987). Students' visualization of a chemical reaction. *Education in chemistry*, *24*(4), 117-120.

Bennett, J., Green, G., Rollnick, M., & White, M. (2001). The development and use of an instrument to assess students' attitudes to the study of science. *Journal of the Southern African Association for Research in Mathematics, Science and Technology Education*, *5*(1), 1-12.

Berg, C. (2005). Factors Related to Observed Attitude Change Toward Learning Chemistry Among University Students. *Chemical Education Research Practice, 6*(1), 1-18.

Berk, L. E., Mann, T. D., & Ogan, A. T. (2006). Make-believe play: Wellspring for development of self-regulation. *Play= learning: How play motivates and enhances children's cognitive and social-emotional growth*, 74-100.

Berson, I. R., & Berson, M. J. (Eds.). (2010). High-tech tots: Childhood in a digital world. A Volume in I. R. Berson & M. J. Berson (Series Eds.) Research in Global Child Advocacy. Charlotte, NC: Information Age Publishing

Bicknell-Holmes, T., & Hoffman, P. (2000). Engage, Elicit, Experience, Explore: Applying Discovery Learning to Library Instruction.

Bitsch, V. (2005). Qualitative research: A grounded theory example and evaluation criteria. *Journal of Agribusiness*, *23*(1), 75-91.

Blum, S. D. (2016). *"I Love Learning; I Hate School"*. Ithaca, NY: Cornell University Press.

Bodner, G. M. (1991). I have found you an argument: The conceptual knowledge of beginning chemistry graduate students. *Journal of Chemical Education*, *68*(5), 385.

Bonwell, C. C., & Eison, J. A. (1991). *Active Learning: Creating Excitement in the Classroom. 1991 ASHE-ERIC Higher Education Reports*. ERIC Clearinghouse on Higher Education, The George Washington University, One Dupont Circle, Suite 630, Washington, DC 20036-1183.

Boo, S. (2015, November 2). As 2020 deadline looms, Malaysian students fail to shine in science. *The Malay Mail Online*. Retrieved from http://www.themalaymailonline.com/malaysia/article/as-2020-deadline-looms-malaysian-students-fail-to-shine-in-science

Bradley, J. D., & Brand, M. (1985). Stamping out misconceptions. *Journal of Chemical Education*, *62*(4), 318.

Bransford J. D., Brown A. L., Cocking R. R., (2000). How People Learn: Brain, Mind, Experience, and School. Committee on Developments in the Science of Learning. National Academies Press, Washington, DC.

Bruner, J. (1960). The Process of Education. Cambridge, MA: Harvard University Press

Buckleitner, W. 2009. "Pocket Rockets: The Past, Present and Future of Children Computing." In A. Druin (Ed.), Mobile Technology for Children, 43-62. Burlin Morgan Kaudmann Publishers.

Burkhardt, H., & Schoenfeld, A. H. (2003). Improving educational research: Toward a more useful, more influential, and better-funded enterprise. *Educational researcher*, *32*(9), 3-14.

Byrne, M., Johnstone, A. H., & Pope, A. (1994). Reasoning in science: a language problem revealed? *School science review*, *75*, 103-103.

Cai, S., Wang, X., & Chiang F. K., (2014). A case study of Augmented Reality Simulation System Application in a Chemistry Course. *Computer in human behaviour, 13*, 31-40

Calvert, S.L., Strong, B. & Gallagher, L. (2005). Control as an engagement feature for young children's attention to, and learning of, computer content. American Behavioral Scientist, 48, 578-589.

Cassels, J. R. T., & Johnstone, A. H. (1983). The meaning of words and the teaching of chemistry. *Education in chemistry*, *20*(1), 10-11.

Chen, M., Wong, Y., & Wang, L. (2014). Effects of type of exploratory strategy and prior knowledge on middle school students' learning of Chemical Formulas from a 3D Role-Playing game. *Education Tech Research Dev. 62*(2),163–185.

Cheng, M. T., Lin, Y. W., & She, H. C. (2015). Learning through playing Virtual Age: Exploring the interactions among student concept learning, gaming performance, in-game behaviors, and the use of in-game characters. *Computers & Education*, *86*, 18-29.

Chew C. M., Noraini I. & Leong K. E. (2014). Secondary students' perceptions of assessments in science, technology, engineering and mathematics (STEM). *Eurasia Journal of Mathematics, Science & Technology Education*, *10*(3), 219-227.

Chiappetta, E. L., & Russell, J. M. (1982). The relationship among logical thinking, problem sloving instruction, and knowledge and application of earth science subject matter. *Science Education*, *66*(1), 85-93.

Childs, P. E., & Sheehan, M. (2009). What's difficult about chemistry? An Irish perspective. *Chemistry Education Research and Practice*, *10*(3), 204-218.

Chiong, C., & Shuler C. (2010). Learning: Is there an app for that? Investigations of young children's usage and learning with mobile devices and apps. New York: The Joan Ganz Cooney Center at Sesame Workshop.

Christakis, D. A. (2014). Interactive media use at younger than the age of 2 years: time to rethink the American Academy of Pediatrics guideline?. *JAMA pediatrics*, *168*(5), 399-400.

Christie, J. & Roskos, K. (2015). How does play contribute to literacy? In Johnson, J., Eberle, S., Henricks, T., & Kuschner, D (Eds.), The handbook of the study of play (pp. 417-424).

Coll, R. K. & Treagust, D. F. (2001). Learners' mental models of chemical bonding, *Research in Science Education*, *31*(3), 357–382.

Collins, A. & Halverson, R. (2009). *Rethinking education in the age of technology: The digital revolution and the schools.* New York, NY: Teachers College Press.

Common Sense Research Study (2012). Children, Teens, and Entertainment Media: The View From The Classroom. A National Survey of Teachers About the Role of Entertainment Media in Students' Academic and Social Development. Retrieved from https://www.commonsensemedia.org/file/view-from-the-classroom...0/download

Connolly, T. M., Stanfield, M., & Hainey, T. (2011). An alternate reality game for language learning: ARGuing for multilingual motivation. *Computers & Education*, *57*, 1389–1415.

Cooper, T., Carroll, S., Liu, C., Chelberg, D., & Franklin, T. (2009, June). Using the virtual world of second life to create educational games for real world middle school science classrooms. In *EdMedia: World Conference on Educational Media and Technology* (pp. 2124-2133). Association for the Advancement of Computing in Education (AACE).

Couse, L.J. & Chen, D.W. (2010). A Tablet Computer for Young Children? Exploring Its Viability for Early Childhood Education. *Journal of Research on Technology in Education*, 43(1) 75-98.

Creswell, J. W. (2014). *Research design: qualitative, quantitative, and mixed methods* approaches (4th ed.). California, CA: SAGE Publications.

Creswell, J. W., & Miller, D. (2000). Determining validity in qualitative inquiry. *Theory Into Practice, 39*(3), 124–130.

Crosswaite, C. & Curtice, L. (1994), Disseminating research results-the challenge of bridging the gap between health research and health action. *Health Promotion International 9*: 289

Csikszentmihalyi, M. (1990). Literacy and intrinsic motivation. *Daedalus*, 115-140.

Cullen, J. B., Levitt, S. D., Robertson, E., & Sadoff, S. (2013). What can be done to improve struggling high schools? *The Journal of Economic Perspectives, 27*(2), 133–152. Retrieved from http://www.jstor.org/stable/23391694

Dahindsa, H.S., & Treagust, D.F. (2009). Conceptual understanding of Bruneian tertiary students: Chemical bonding and structure. *Brunei International Journal of Science and Mathematics Education, 1*(1), 33-51.

de Freitas, S., & Griffiths, M. (2007), Online gaming as an educational tool in learning and training. British Journal of Educational Technology, 38: 535–537.

de Jong, T., & van Joolingen, W. R. (1998) Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research, 68,* 179–202.

Dede, C., Clarke, J., Ketelhut, D., Nelson, B., & Bowman, C. (2005). Fostering Motivation, Learning, and Transfer in Multi-User Virtual Environments. Paper presented at the American Educational Research Association Conference, Montreal.

Devlin, K. (2011). *Mathematics education for a new era: Video games as a medium for learning*. Natick, Mass.: A K Peters

Devlin, T.J., Feldhaus, C.R., & Bentrem, K.M. (2013). The evolving classroom: A study of traditional and technology-based instruction in a STEM classroom. *Journal of Technology Education, 25* (1). Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v25n1/devlin.html

Dewey, J. (1913). *Interest and effort in education*. Boston: Riverside Press.

Dewey, J. (1938). *Experience and Education*: New York, NY: Macmillan.

Dewey, J. (1944). Democracy and education: An introduction to the philosophy of education. New York, NY: The Free Press

Di Serio, A., Ibanez, M. B., & Kloos, C. D. (2013). Impact of an Augmented Reality on Students' Motivation for a Visual Art Course. *Computers & Education, 68*, 586-596.

Dickinson, D. K., & Tabors, P. O. (2001). *Beginning literacy with language: Young children learning at home and school*. Paul H Brookes Publishing.

Dickey, M. D. (2005). Engaging by design: How engagement strategies in popular computer and video games and inform instructional design. *Educational Technology Research and Development, 53*, 67–83.

Dickey, M. D. (2007). Game design and learning: a conjectural analysis of how massively multiple online role-playing games (MMORPGs) foster intrinsic motivation. *Educational Technology Research and Development*, *55*, 253–273.

Dominguez, A., Oliver, E., Cebolla, A., Albertini, S., Ferrini, L., Gonzalez, A.,... Banos, C. (2016). Serious games to teach nutrition education to children between 9 to 12 years old. Pickit! & Cookit!. Paper presented at EAI International Conference on Games for WELL-being, At Budapest, Hungary. Retrieved from https://www.researchgate.net/publication/309380606_Serious_Games_to_Teach_Nutrition_Education_to_Children_between_9_to_12_years_old_Pickit_Cookit

Entertainment Software Association, (2006). Essential Facts About the Computer and Video Game Industry. Retrieved from https://library.princeton.edu/sites/default/files/2006.pdf

Elias, C. L., & Berk, L. E. (2002). Self-regulation in young children: Is there a role for sociodramatic play? *Early Childhood Research Quarterly*, *17*(2), 216-238.

Elkind, D. (2008). The Power of Play: Learning What Comes Naturally. *American Journal of Play*, *1*(1), 1-6.

Fabricatore, C. (2007). Gameplay and Game Mechanics: A Key to Quality in Videogames. OECD Expert Meeting on Videogames and Education, 29-31 October, 2007, Retrieved from http://www.oecd.org/dataoecd/44/17/39414829.pdf

Farber, M. (2015). *Gamify your classroom: A field guide to game-based learning*. New York, NY: Peter Lang Publishing, Inc.

Farhana W. Y. & Zainun M. A. (2013). Attitude towards learning chemistry among secondary school students in Malaysia. *Journal of Asian Behavioural Studies, 3* (11), 1-11.

Fensham, P. J. (Ed.). (1988). *Development and dilemmas in science education* (Vol. 23). Psychology Press.

Frank, A. (Sept. 8, 2016). World of Warcraft sees big numbers hot off Legion launch. http://www.polygon.com/2016/9/8/12851794/world-of-warcraft-legion-sales-launch-day-subscribers-record

Freedman, M. P. (1997). Relationship among laboratory instruction, attitude toward science, and achievement in science knowledge. *Journal of research in science teaching*, *34*(4), 343-357.

Freeman, S., O'Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., Dirks, C., Wenderoth, M. P., (2007). Prescribed active learning increases performance in introductory biology. *CBE Life Sci. Educ., 6*,132–139.

Froebel, F. (1887). The education of man.(WN Hailmann, Trans.) New York: Appleton.

Fromberg, D. P., & Gullo, D. F. (1992). Perspectives on Children. *Williams, LR & Fromberg, DP Encyclopedia of Early Childhood Education. NY: Garland Publishing, Inc*.

Frost, J. L. (1992). Reflections on Research and Practice in Outdoor Play Environments. *Dimensions of Early Childhood, 20*(4), 6-10.

Fullan, M. (2013). *Stratosphere: Integrating technology, pedagogy, and change knowledge*. Toronto, ON: Pearson

Gabel, D. (1999). Improving teaching and learning through chemistry education research: A look to the future. *Journal of Chemical education*, *76*(4), 548.

Garner, R. (1992). Learning from school texts. *Educational Psychologist*, *27*(1), 53-63.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, Motivation, and Learning: A Research and Practice Model. *Simulation & Gaming* 33(4) 441-467.

Gates, B. (2005, February 26). Prepared remarks. *National Education Summit on High Schools*. Retrieved from http://www.admin.mtu.edu/ctlfd/Ed%20Psych%20Readings/BillGate.pdf

Gazzard, A. (2011). Unlocking the Gameworld: The Rewards of Space and Time in Videogames. *The International Journal of Computer Game Research,11*(1). Retrieved from http://gamestudies.org/1101/articles/gazzard_alison

Gee, J. P. (2003). What video games have to teach us about learning and literacy. *Computers in Entertainment (CIE)*, *1*(1), 20-20.

Gee, J. P. (2004). *Situated language and learning: A critique of traditional schooling*. Psychology Press.

Gee, J. P. (2007). *What video games have to teach us about learning and literacy* (2nd ed.), New York, NY: Palgrave Macmillan.

Gee, J. P. (2009). Deep learning properties of good digital games: How far can they go? In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.) *Serious games: Mechanisms and effects.* (pp. 67–82). New York, NY: Routledge.

Gee, J. P., & Shaffer, D. W. (2010). Looking where the light is bad: Video games and the future of assessment. (Epistemic Games Group Working Paper No. 2010–02). Madison: University of Wisconsin-Madison. Retrieved from http://epistemicgames.org/eg/looking-where-the-light-is-bad/

Gibbs, G. R. (2007). Thematic Coding and Categorizing, Analyzing Qualitative Data. SAGE Publications Ltd., London.

Gillispie, L., Martin, F., & Parker, M. A. (2010). Effects of a 3-D video game on middle school student achievement and attitude in mathematics. *Electronic Journal of Mathematics and Technology*, *4*(1), 68–80.

Ginsburg, K. R. (2007). The Importance of Play in Promoting Healthy Child Development and Maintaining Strong Parent-Child Bonds. *Pediatrics*, *119* (1) pp182

Ginsburg, H. P., Lee, J. S., & Boyd, J. S. (2008). Mathematics Education for Young Children: What It Is and How to Promote It. Social Policy Report. *Society for Research in Child Development*, *22*(1).

Glasman, L. R., & Albarracin, D. (2006). Forming attitudes that predict future behavior: A meta-analysis of the attitude-behavior relation. *Psychological bulletin*, *132*(5), 778.

Groff, J., Howells, C., & Cranmer, S. (2010). *The impact of console games in the classroom: Evidence from schools in Scotland.* UK: Futurelab.

Hallford N. & Hallford, J. (2001). *Swords and Circuitry: A designer's guide to computer role playing games.* Roseville, CA: Prime Publishing

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does Gamification Work? – A Literature Review of Empirical Studies on Gamification. In *proceedings of the 47th Hawaii International Conference on System Sciences,* Hawaii, USA, January 6-9, 2014.

Hamari, J.; Shernoff, D. J.; Rowe, E.; Coller, B.; Asbell-Clarke, J.; Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior, 54*, 170-179.

Handelsman J., (2004). Scientific teaching. *Science, 30*, 521–522.

Handelsman, J., Miller, S., & Pfund, C., (2007). Scientific Teaching. W.H. Freeman, New York, NY

Harackiewicz, J. M., Barron, K. E., Carter, S. M., Lehto, A. T., & Elliot, A. J. (1997). Predictors and consequences of achievement goals in the college classroom: Maintaining interest and making the grade. *Journal of Personality and Social Psychology, 73*, 1284-1295.

Hattie, J. (2009). The contributions from teaching approaches-part 1. *J. Hattie.(Eds.), Visible learning: A synthesis of over, 800*, 161-199.

Hattie, J. (2012). *Visible learning for teachers*. London, ENG: Routledge.

Hawkes-Robinson, W. A. (2011). Role-playing Games Used as Educational and Therapeutic Tools for Youth and Adults. Retrieved from http://rpgresearch.com/documents/rpg-research-documents/RPGR-A004-Role-playing-Games-Used-as-Educational-and-Therapeutic-Tool-for-Youth-and-Adults-Ver-2-20111206e.pdf/view

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research*, *60*, 549-571.

Hirsh-Pasek, K., Golinkoff, R. M., & Eyer, D. E. (2003). *Einstein never used flashcards: How our children really learn – and why they need to play more and memorize less*. Rosedale.

Hirsh-Pasek, K., Golinkoff, R., Berk, L., & Singer, D. (2009). *A mandate for playful learning in preschool: Presenting the evidence*. New York, NY: Oxford University Press.

Hitchens, M., & Drachen, A., (2008). The Many Faces Of Role-Playing Games. *International Journal of Role-Playing, 1*(1), 3-21

Hofstein, A. & Mamlok-Naaman, R., (2011). High-School Students' Attitudes toward and Interest in Learning Chemistry. *Science Education International, 22*(1), 5-17

Holzinger, A., Kickmeier-Rust, M., & Albert, D. (2008). Dynamic media in computer science education; content complexity and learning performance: is less more? *Educational Technology & Society*, *11*(1), 279–290.

Horn, M. (2015). Children should advance in school according to skill, not age. Quartz. Retrieved from http://qz.com/432308/children-should-advance-in-school-according-to-skill-not-age/

Howe, N. and Strauss, W. (2000). Millennials Rising: The Next Great Generation. New York: Vintage Books.

Hsieh, T. H. & Huang, H. C., (2014). "Happy studying by gamificational role playing. In Orange Technologies (ICOT)", *2014 IEEE International Conference on*, pp. 69-72, 2014, September.

Hu, W. (2011, January 4). Math that moves: Schools embrace the iPad. *The New York Times*. Retrieved from http://www.nytimes.com/2011/01/05/education/05tablets.html

Huizinga, J. (1955). 1938. *Homo Ludens: A Study of the Play Element in Culture*.

Hussain, S. Y. S., Tan, W. H., & Idris, M. Z. (2014). Digital game-based learning for remedial mathematics students: A new teaching and learning approach In Malaysia. *International Journal of Multimedia Ubiquitous Engineering, 9*(11), 325-338.

International Society for Technology in Education (2007). ISTE Standards for Students. Retrieved from http://www.iste.org/standards/standards/for-students-2007

Johnstone, A.H., (1974). Evaluation of Chemistry Syllabuses in Scotland, *Studies in Science Education, 1*, 20-49.

Johnstone, A., & Cassels, J. (1978). What's in a word?. *IEEE Transactions on Professional Communication*, *21*(4), 165-167.

Johnstone, A. H. (1984). New Stars for the Teacher to Steer by? *Journal of Chem. Educ.*, *61* (10), p 847.

Johnstone, A. H. (1991), Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning, 7*: 75–83.

Johnstone, A. H. (2000). Teaching of chemistry-logical or psychological?. *Chemistry Education Research and Practice*, *1*(1), 9-15.

Johnson, L., Smith, R., Willis, H., Levine, A., & Haywood, K. (2011). The 2011 Horizon Report. Austin, TX: The New Media Consortium. In *International Conference on Educational Data Mining. Montréal, Québec, Canada* (pp. 38-70).

Kang, S.C. (December 8, 2013). Poor Show in Pisa Rankings. The Star Online. Retrieved from http://www.thestar.com.my/News/Education/2013/12/08/Poor-show-in-Pisa-rankings/

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. In R. E. Furdig (Ed.) *Handbook of Research on Effective Electronic Gaming in Education* (pp. 1–32), New York: IGI Global

Kelly, A. (1988). Ethnic differences in science choice, attitudes and achievement in Britain. *British Educational Research Journal*, *14*(2), 113-126.

Kelly, F. S., McCain, T., & Jukes, I. (2009). Teaching the Digital Generation: No More Cookie-Cutter High Schools. Melbourne: Hawker Brownlow Education.

Kerawalla, L., & Crook, C (2002), Children's computer use at home and at school: context and continuity, British Educational Research Journal, 28, 751-771.

Ketelhut, D. J., Dede, C., Clarke, J., & Nelson, B. (2006, April). A multi-user virtual environment for building higher order inquiry skills in science. Paper presented at the 2006 AERA Annual Meeting, San Francisco, CA. Retrieved from http://muve.gse.harvard.edu/rivercityproject/documents/rivercitysympinq1.pdf

Khan, S. (2012). *The one world schoolhouse: Education reimagined*. New York, NY: Twelve Hachette Book Group.

Kickmeier-Rust, M. D., Hockemeyer, C., Albert, D., & Augustin, T. (2008, November). Micro adaptive, non-invasive knowledge assessment in educational games. In *Digital Games and Intelligent Toys Based Education, 2008 Second IEEE International Conference on* (pp. 135-137). IEEE.

Kind, V. & Kind, P.M (2011). Beginning to teach Chemistry: How personal and academic characteristics of pre-service science teachers compare with their understandings of basic chemical ideas. *International Journal of Science Education 33*(15), 2123–2158

Kingsley, K., & Unger, J. (2008, March). Classroom teachers' experiences with critical inquiry and multimedia literacy. In *Society for Information Technology & Teacher Education International Conference* (pp. 4195-4200). Association for the Advancement of Computing in Education (AACE).

Kist, W. (2003). Student achievement in new literacies for the 21st century. *Middle School Journal*, *35*(1), 6-13.

Klopfer, E., Osterweil, S., & Salen, K. (2009). Moving learning games forward. *Cambridge, MA: The Education Arcade*.

Knight J. K., & Wood W. B., (2005). Teaching More By Lecturing Less. *Cell Biol. Educ.*, *4*,298–310.

Koenig, A. D., Lee, J. J., Iseli, M., & Wainess, R. (2010). A Conceptual Framework for Assessing Performance in Games and Simulations. CRESST Report 771. *National Center for Research on Evaluation, Standards, and Student Testing (CRESST).*

Kong, S. C. (1993). Minat pelajar terhadap sains dan teknologi: Satu pandangan sedunia. *Buletin JNSP*, V (III), 15-21.

Kozma, R. B., & Russell, J. (1997). Multimedia and understanding: Expert and novice responses to different representations of chemical phenomena. *Journal of Research in Science Teaching*, *34*(9), 949-968.

Kpolovie, P. J., Joe, A. I., & Okoto, T., (2014). Academic Achievement Prediction: Role of Interest in Learning and Attitude towards School. *International Journal of Humanities Social Sciences and Education*, *1*(11), 73-100. Retrieved online from https://www.arcjournals.org/pdfs/ijhsse/v1-i11/10.pdf

Krapp, A., Hidi, S., & Renninger, K.A. (1992). Interest, learning and development. In K.A. Renninger, S. Hidi, & A. Krapp (Eds.),*The role of interest in learning and development* (pp. 3–25). Hillsdale, NJ: Erlbaum.

Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 183-212). Hillsdale, NJ: Lawrence Erlbaum Associates.

Krapp, A., (1999). Interest, Motivation and Learning: An educational psychological perspective. *European Journal of Psychology of Education 14*(1), 23-40. Retrieved from https://doi.org/10.1007/BF03173109

Laamarti, F., Eid, M., & El Saddik, A., (2014). An Overview of Serious Games, *International Journal of Computer Games Technology*, vol. 2014,

Larson, R. W. (2000). Toward a psychology of positive youth development. The American Psychologist, 55, 170–183.

Lassiter, G. D., Geers, A. L., Munhall, P. J., Handley, I. M., & Beers, M. J. (2001). Videotaped confessions: Is guilt in the eye of the camera? In M. P. Zanna (Ed.), Advances in experimental social psychology (pp. 189–254). New York, NY: Academic Press.

Lawton, J. T., Saunders, R. A., & Muhs, P. (1980). Theories of Piaget, Bruner, and Ausubel: Explications and Implications. *The Journal of Genetic Psychology, 136*(1), 121-136

Lave, J., & Wenger, E. (1991). Situated Learning: Legitimate Periperal Participation. Cambridge, UK: Cambridge University Press.

Leon, A. C., et al., (2011). The role and interpretation of pilot studies in clinical research. *Journal of Psychiatric Research , 45*(5): 626 – 629

Levin, D., & Arafeh, S. (2002). The Digital Disconnect: The Widening Gap between Internet-Savvy Students and Their Schools. Retrieved from https://eric.ed.gov/?id=ED471133.

Levine, A. (2006). Educating school teachers. *Education Schools Project*.

Lincoln, Y. S., & Guba E. G. (1985). Naturalistic inquiry. Beverly Hills, CA: Sage Publications Inc.

Lisenbee, P. (2009). Whiteboards and Web Sites: Digital Tools for the Early Childhood Curriculum. Young Children, 64(6), 92-95.

Lombard, M., & Ditton T. (1997). At the heart of it all: the concept of presence. *Journal of Computer Mediated Communication*, *3*(2). Retrieved from http://jcmc.indiana.edu/vol3/issue2/lombard.html.

Loukomies, A., Pnevmatikos, D., Lavonen, J. et al. (2013). *Research in Science Education, 43*(6), 2517-2539.

Maehr, M. L., & Meyer, H. A. (1997). Understanding Motivation and Schooling: Where We've Been, Where We Are, and Where We Need to Go. *Educational Psychology Review, 9*(4), 371-409.

Malaysian Communications and Multimedia Commission, MCMC, (2016). Internet Users Survey 2016: Statistical Brief Number Twenty. Retrieved from https://www.mcmc.gov.my/skmmgovmy/media/General/pdf/IUS2016.pdf

Malaysia Education Blueprint 2013-2025. (2013). Preliminary Report. Preschool to Post-Secondary Education. Ministry of Education Malaysia.

Marbach-Ad G., Seal O., & Sokolove P., (2001). Student attitudes and recommendations on active learning: a student-led survey gauging course effectiveness. *J. Coll. Sci. Teach., 30,* 434–438.

Marzano, R. J., Pickering, D., & Pollock, J. E. (2001). *Classroom instruction that works: Research-based strategies for increasing student achievement*. Ascd.

Mason, P., (2004). In Search of the Self, A Survey of the First 25 Years of Anglo-American Role- Playing Theory. In M. Montola, M. & J. Stenros, J. eds. *Beyond Role and Play: Tools, Toys and Theory for Harnessing the Imagination*, Helsinki: Ropecon, p.1-14. [Online]. Available at: http://www.ropecon.fi/brap/brap.pdf

Matzin, N. A. & Wong, S. Y. (2013). Design and evaluation of history digital game based learning (DGBL) software. *Journal of Next Generation Information Technology*, 4, 9.

McCrindle, M. (2011). Generations Defined. The ABC of XYZ. Retrieved from http://mccrindle.com.au/resources/whitepapers/McCrindle-Research_ABC-01_Generations-Defined_Mark-McCrindle.pdf

McLeod, S. A. (2008). Bruner. Retrieved from www.simplypsychology.org/bruner.html

McLeod, S. A. (2014). Lev Vygotsky. Retrieved from www.simplypsychology.org/vygotsky.html

Michael, D., & Chen, S. (2005). *Serious Games: Games That Educate, Train, and Inform* (1er ed.). Course Technology PTR.

Ministry of Education (2012). Laporan Strategi Mencapai Dasar 60:40 Aliran Sains Teknikal: Sastera (ms 82). Putrajaya, KPM.

Mitchell, A., & Savill-Smith, C. (2004). The use of computer and video games for learning: a review of the literature. London: Learning and Skills Development Agency

Montessori, M., & Carter, B. (1936). The secret of childhood. Bombay: Orient Longmans.

Mraz, K., Porcelli, A., & Tyler, C. (2016). *Purposeful Play: A Teacher's Guide to Igniting Deep and Joyful Learning Across the Day*. Heinemann.

Muzammila Akram, Johari Bin Surif & Murad Ali (2014). Conceptual Difficulties of Secondary School Students in Electrochemistry. *Asian Social Science*; *10*(19), 276 – 281.

Nakhleh, M. B. (1992). Why some students don't learn chemistry: Chemical misconceptions. *Journal of chemical education*, *69*(3), 191.

National Council for Accreditation of Teacher Education (2008). Professional Standards for the Accreditation of Teacher Preparation Institutions. Retrieved from http://www.ncate.org/~/media/Files/caep/accreditation-resources/ncate-standards-2008.pdf?la=en

National Research Council (NRC), (1999). Transforming Undergraduate Education in Science, Mathematics, Engineering and Technology. National Academies Press, Washington, DC.

National Research Council (NRC), (2007). Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. Committee on Prospering in the Global Economy of the 21st Century: An Agenda for American Science and Technology. National Academies Press, Washington, DC.

Nicoll, G. (2001). A report of undergraduates' bonding misconceptions. *International Journal of Science Education*, *23*(7), 707-730.

Olson, G. (1997). Motivation, Motivation, Motivation - Secondary School Educators. Retrieved from sysiwyg://934/http://7-12educators.about...-12educators/library/weekly/aa071897.htm.

O'Neil, H. F., Wainess, R., & Baker, E. L. (2005). Classification of learning outcomes: Evidence from the computer games literature. *The Cirriculum Journal*, *16*(4), 455-474.

Osborne, J., & Collins, S. (2000). *Pupils'& parents' views of the school science curriculum*. London: Kings College.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International journal of science education*, *25*(9), 1049-1079.

Osman, K. & Bakar, N. A. (2012). Educational computer games for Malaysian classrooms: Issues and challenges. *Asian Social Science, 8*(11), 75.

Ozmen, H. (2004). Some student misconceptions in chemistry: A literature of chemical bonding. *Journal of Science Education and Technology, 13*, 146-159.

Palmer, D. (2007). What Is the Best Way to Motivate Students in Science? *Teaching Science-The Journal of the Australian Science Teachers Association*, *53*(1), 38-42.

Papalia, D., Olds, S., & Feldman, R. (2011). A child’s world: infancy through adolescence, 11th ed. Boston: McGraw-Hill Higher Education

Papastergiou, M. (2009). Digital game-based learning in high school computer science education: impact on educational effectiveness and student motivation. *Computers & Education, 52*, 1–12.

Papert, S. & Markowsky, G. (2013). The state of learning. LEARNing Landscapes | 6 (2) Spring 2013. Retrieved from http://www.learninglandscapes.ca/images/documents/ll-no12/papert.pdf

Partnership for 21st Century Learning (2009). P21 Framework definitions. Retrieved from http://www.p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf

Patton, M. Q. (1990). *Qualitative Evaluation and Research Methods* (2nd ed.). Newbury Park, CA: Sage Publications, Inc.

Pausch, R. (2007). *The Last Lecture: Really Achieving Your Childhood Dreams*. Carnegie Mellon Unversity. Retrieved from http://www.cmu.edu/randyslecture/

Pawelczyk, K. & Kuldip Kaur, K. S. (2014). Exploring the Digital Landscape in Malaysia: Access and use of Digital Technologies by Children and Adolescents. United Nations Children's Fund (UNICEF) Malaysia.

Pew Research Center (3, September, 2015). The Whys and Hows of Generations Research. Retrieved from http://www.people-press.org/2015/09/03/the-whys-and-hows-of-generations-research/

Piaget, J. (1951). *Play, dreams and imitation in childhood*. Retrieved from http://web.media.mit.edu/~ascii/papers/piaget_1952.pdf

Piaget, J. (1959). *The language and thought of the child (3rd ed.).* New York, NY: Humanities Press.

Piaget, J. (1971). Biology and knowledge: An essay on the relations between organic regulations and cognitive processes.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology*, *95*(4), 667-686.

Pintrich, P. R., Smith, D., Garcia, T., and McKeachie, W. (1993). Predictive validity and reliability of the Motivated Strategies for Learning Questionnaire (MSLQ). Educ. Psychol. Meas. 53: 801–813.

Prensky, M. (2001a). Digital natives digital immigrants. *On the Horizon*, *9*(5). MCB, University Press.

Prensky, M. (2001b). *Digital Game-Based Learning*. New York, NY: McGraw-Hill.

Prensky, M. (2006). *Don't bother me, Mom, I'm learning!: How computer and video games are preparing your kids for 21st century success and how you can help!*. St. Paul, MN: Paragon house.

Prensky, M. (2007) Students as Designers and Creators of Educational Computer Games, Who Else?. Students as Educational Game Designers

Prensky, M. (2011). Digital wisdom and homo sapiens digital. *Deconstructing digital natives: Young people, technology and the new literacies*, 15-29.

Preszler, R. W., Dawe, A., Shuster, C. B., & Shuster, M., (2007). Assessment Of The Effects Of Student Response Systems On Student Learning And Attitudes Over A Broad Range Of Biology Courses. *CBE Life Sci. Educ.*, *6*, 29–41

Prince M., (2004). Does Active Learning Work? A Review Of The Research. *J. Eng. Educ.*, *93*, 223–231

PRNewswire (9 March 2016). ChemCaper: Reinventing Education with the World's First Chemistry RPG Game. Retrieved from http://en.prnasia.com/story/144366-0.shtml

Project Kaleidoscope, (2006). Recommendations for Urgent Action in Support of Undergraduate Science, Technology, Engineering, and Mathematics. Washington, DC:

Project Zero, & Reggio Children (2001). *Making learning visible: Children as individual and group learners*. Reggio Emilia, Italy: Reggio Children.Google Scholar

Pugh, K.J. & Bergin, D.A. (2006) Motivational Influences on Transfer. *Educational Psychologist*, 41(3), 147-160.

Raman, A. & Abdul Halim, M. (2013). Issues of ICT usage among Malaysian secondary school English teachers. *English Language Teaching*, *6*(9), 74-82. Retrieved from http://www.ccsenet.org/journal/index.php/elt/article/viewFile/29645/17582

Ramey, K. E., Champion, D. N., Dyer, E. B., Keifert, D. T., Krist, C., Meyerhoff, P.,… Hilppö, J. (2016). Qualitative Analysis of Video Data: Standards and Heuristics In Looi, C. K., Polman, J. L., Cress, U., & Reimann, P. (Eds.). Transforming Learning, Empowering Learners: The International Conference of the Learning Sciences (ICLS) 2016, Volume 2. Singapore: International Society of the Learning Sciences.

Randi, M. A. R. & de Carvalho, H. F., (2013). Learning Through Role-Playing Games: an Approach for Active Learning and Teaching. *Revista Brasileira De Educação Médica*. *37*(1), 80-88.

Rankin, Y., Gold, R. & Gooch, B. (2006). 3D Role-Playing Games as Language Learning Tools. *Eurographics*, *25*(3). Retrieved from https://pdfs.semanticscholar.org/273d/1b6216069f85091da1b69f9ce4d02b65c0c8.pdf

Rapini, S. (2012). *Beyond textbooks and lectures: Digital Game-Based Learning in STEM subjects*. McLean, Virgina, VA: Center For Excellence in Education.

Rees, C.A.B. (2015). Developing Science literacy through the Heat Game: An online Role-Playing game. *International Journal for Leadership in Learning, 1*(3). Retrieved from https://www.learntechlib.org/p/158713

Resnick, L. B. (1987). *Education and learning to think*. National Academies.

Rideout, V., Lauricella, A., & Wartella, E. (2011). Children, media and race: Media use among White, Black, and Hispanic, and Asian American children. Report of the Center on Media and Human Development School of Communication Northwestern University

Robertson, J., & Howells, C. (2008). Computer game design: opportunities for successful learning. *Computers & Education*, *50*, 559–578

Robinson, K. & Aronica, L. (2016). *Creative Schools: The Grassroots Revolution That's Transforming Education*. London, UK: Penguin Random House.

Rooney, P. (2012). A Theoretical framework for serious game design: Exploring pedagogy, play and fidelity and their implications for the design process. *International Journal of Game-based Learning, 2*(4) 41-60. Retrieved from http://arrow.dit.ie/cgi/viewcontent.cgi?article=1027&context=ltcart

Rosen, L.D., Carrier, L.M. & Cheever, N. A. (2010). *Rewired: Understanding the iGeneration and the Way They Learn*. New Your, NY: Palgrave Macmillan.

Rosen, L. D. (2011). Teaching the iGeneration. *Educational Leadership*, *68*(5), 10-15. Retrieved from http://www.ascd.org/publications/educational-leadership/feb11/vol68/num05/Teaching-the-iGeneration.aspx

Rupp, A. A., Gushta, M., Mislevy, R. J., & Shaffer, D. W. (2010). Evidence-centered design of epistemic games: Measurement principles for complex learning environments. *The Journal of Technology, Learning and Assessment, 8*(4).

Salen, K., & Zimmerman, E. (2004). *Rules of play: Game design fundamentals*. MIT press.

Salta, K., & Tzougraki, C. (2004). Attitudes toward chemistry among 11th grade students in high schools in Greece. *Science Education*, *88*(4), 535-547.

Samuel, R.J. & Zaitun, A.B. (2007). Do Teachers Have Adequate ICT Resources and the Right ICT Skills in Integrating ICT Tools in the Teaching and Learning of English Language in Malaysian Schools? *The Electronic Journal on Information Systems in Developing Countries*, *29*(2) 1-15. Retrieved from http://www.ejisdc.org/ojs2/index.php/ejisdc/article/view/283/195

Saracho, O. N. & Spodek, B. (2006). Young children's literacy-related play. *Early Child Development and Care, 176*(7), 707-721.

Schiefele, U. (1991). Interest, Learning and Motivation. *Educational Psychologist*, *26*(3 & 4), 299-323. Retrieved from http://www.unco.edu/cebs/psychology/kevinpugh/motivation_project/resources/schiefele91.pdf

Schraw, G., Bruning, R., & Svoboda, C. (1995). Sources of situational interest. *J. Reading Behav*. 27: 1–17.

Schraw, G., Flowerday, T., & Lehman, S. (2001). Increasing situational interest in the classroom. *Educational Psychology Review, 13*(3) 211–224.

Sedig, K. (2008). From play to thoughtful learning: a design strategy to engage children with mathematical representations. *Journal of Computers in Mathematics and Science Teaching*, *27*(1), 65–101.

Shaffer, D. W. (2004). Pedagogical praxis: The professions as models for postindustrial education. *Teachers College Record*, *106*(7), 1401-1421.

Shaffer, D. W. (2009). Wag the kennel: Games, frames, and the problem of assessment. In *Handbook of research on effective electronic gaming in education* (pp. 577-592). IGI Global.

Sjøberg, S., & Schreiner, C. (2005a). Young people and science. In *Attitudes, values and priorities. Evidence from the ROSE project. Keynote presentation at EU's Science and Society Forum* (pp. 9-11).

Sjøberg, S., & Schreiner, C. (2005b). How do learners in different cultures relate to science and technology? Results and perspectives from the project ROSE (the Relevance of Science Education). In *Asia-Pacific Forum on Science Learning and Teaching* (Vol. 6, No. 2, pp. 1-17). The Education University of Hong Kong, Department of Science and Environmental Studies.

Sousa, D. A., & Tomlinson, C. A. (2011). *Differentiation and the brain: How neuroscience supports the learner-friendly classroom*. Solution Tree Press.

Spykerman, N., & Lee, P. (2015, September 23). 'Find out why students shying away from science subjects'. *The Star Online*. Retrieved from http://www.thestar.com.my/news/nation/2015/09/23/find-out-why-students-shying-away-from-science-subjects/

Squire, K., Barnett, M., Grant, J. M., & Higginbotham, T. (2004, June). Electromagnetism supercharged!: learning physics with digital simulation games. In *Proceedings of the 6th international conference on Learning sciences* (pp. 513-520). International Society of the Learning Sciences. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.96.797

Squire, K. (2006). From content to context: Videogames as designed experience. *Educational researcher*, *35*(8), 19-29.

Squire, K. (2011). *Video games and learning: Teaching and participatory culture in the digital age*. New York, NY: Teachers College Press.

Stark, R., & Gray, D. (1999). Gender preferences in learning science. *International journal of science education*, *21*(6), 633-643.

Stewart, J., Bleumers, J., Van Looy, J., Mariln, I., All, A., Schurmans, D.,…Misuraca, G. (2013). The potential of digital games for empowerment and social inclusion of groups at risk of social and economic exclusion: Evidence and opportunity for policy. Joint Research Centre of the European Commision.

Stofflett, R. T., (1998). Putting Constructivist Teaching into Practice in Undergraduate Introductory Science. *Electronic Journal of Science Education*, *3*(2). Retrieved from http://unr.edu/homepage/jcannon/ejse/stofflett.html.

Taber, K. S., (2002). *Alternative Conceptions In Chemistry: Prevention, Diagnosis and Cure?* London, ENG: The Royal Society of Chemistry.

Takeuchi, L. M., & Vaala, S. (2014). Level up learning: A national survey on teaching with digital games. New York: The Joan Ganz Cooney Center at Sesame Workshop.

Tapscott, D. (2009). *Grown up digital* (Vol. 361). New York: McGraw Hill.

Teijlingen van, E., Rennie, A.M., Hundley, V., & Graham, W. (2001), The importance of conducting and reporting pilot studies: The example of the Scottish Births Survey, *Journal of Advanced Nursing 34*: 289-295.

The President's Council of Advisors on Science and Technology Executive Report (2010). *Prepare and Inspire: K-12 Science, Technology, Engineering, and Math (STEM) Education for America's Future*. Retrieved from https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf

Thorndike, E.L. (1935). *The psychology of wants, interests, and attitudes*. New York, NY: Appleton-Century.

Tolbize, A. (2008). Generational differences in the workplace. *Research and training center on community living*, *5*(2), 1-21.

Torrente, J., Moreno-Ger, P., Martínez-Ortiz, I., & Fernandez-Manjon, B. (2009). Integration and deployment of educational games in e-learning environments: The learning object model meets educational gaming. *Journal of Educational Technology & Society*, *12*(4).

Tsai, F. H., Yu, K. C., & Hsiao, H. S. (2012). Exploring the Factors Influencing Learning Effectiveness in Digital Game-based Learning. *Educational Technology & Society*, *15*(3), 240–250.

Udovic, D., Morris, D., Dickman, A., Postlethwait, J., & Wetherwax, P., (2002). Workshop Biology: Demonstrating The Effectiveness Of Active Learning In An Introductory Biology Course. *Bioscience, 52*, 272–281

Van Eck, R. (2006). Digital game-based learning: It's not just the digital natives who are restless. *EDUCAUSE Review*, *41*(2), 16-30.

Van Eck, R. (2015). Digital game-based learning: Still restless, after all these years. *Educause Review*, *50*(6), 13-28.

Victoria, J. R., Ulla G. F. & Donald, F. R. (2010). Generation M^2, Media in the Lives of 8- to 18-Year-Olds. The Henry J. Kaiser Family Foundation. Retrieved from https://files.eric.ed.gov/fulltext/ED527859.pdf

Vygotsky, L. S. (1932). On the Problem of the Psychology of the Actor's Creative Work. *Collected Works of L.S. Vygotsky*. 6, 237-244

Vygotsky, L. S. (1967). Play and Its Role in the Mental Development of the Child, *Soviet Psychology, 5*(3), 6-18. DOI: 10.2753/RPO1061-040505036

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Weiland, C., & Yoshikawa, H. (2013). Impacts of a prekindergarten program on children's mathematics, language, literacy, executive function, and emotional skills. *Child Development, 84*(6), 2112-2130.

Weimer M., (2002). *Learner-Centered Teaching: Five Key Changes to Practice*. San Francisco, CA: Jossey-Bass.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in science Teaching*, *32*(4), 387-398.

Wiggins, G. (2013, November 18). Attention teachers! Why students are bored. *The Huffington Post*. Retrieved from http://www.huffingtonpost.com/grant-wiggins/why-students-are-bored_b_4274474.html

Williams, M. K., Foulger, T., & Wetzel, K. (2010, March). Aspiring to reach 21st century ideals: Teacher educators' experiences in developing their TPACK. In *Society for Information Technology & Teacher Education International Conference* (pp. 3960-3967). Association for the Advancement of Computing in Education (AACE).

Williams, R. (2016, September 26). I Just Sued The School System !!!. (Video file). Retrieved from https://www.youtube.com/watch?v=dqTTojTija8

Woempner, C. (2007). *Teaching the next generation. Mid-continent Research for Education and Learning*, pp. 1-4. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v25n1/devlin.html#woempner

Woldeamanuel, M. M., Atagana, H., & Engida, T. (2014). What Makes Chemistry Difficult. *AJCE*, *4*(2), Special Issue (Part I), 31-43.

Wright, S. (2013, November 14). Why academic teaching doesn’t help kids excel in life. *Mindshift KQED News*. Retrieved from https://ww2.kqed.org/mindshift/2013/11/14/why-academic-teaching-doesnt-help-kids-excel-in-life/

Zakaria, E., & Iksan, Z. (2007). Promoting Cooperative Learning in Science and Mathematics Education: A Malaysian Perspective. *Online Submission*, *3*(1), 35-39.

Zeidler, D. L., Lederman, N. G., & Taylor, S. C. (1992). Fallacies and student discourse: Conceptualizing the role of critical thinking in science education. *Science Education*, *76*(4), 437-450.

Zimmerman, E. (2003). *Rules of play: Game design fundamentals*. Cambridge, Mass.: MIT Press.

Zohar, A., & Tamir, P. (1993). Incorporating critical thinking into a regular high school biology curriculum. *School Science and Mathematics*, *93*(3), 136-140.

Zoller, U. (1990). Students' misunderstandings and misconceptions in college freshman chemistry (general and organic). *Journal of Research in Science Teaching*, *27*(10), 1053-1065.

Zoller, U. (2000). Teaching Tomorrow’s College Science Courses-Are We Getting It Right? *Journal of College Science Teaching*, *29*(6), 409-414.