



UNIVERSIDADE CATÓLICA PORTUGUESA

**USER-GENERATED GAME DESIGN FOR CREATIVITY IN EDUCATION
AUDIO-VISUAL AND TANGIBLE USER INTERACTION MODELS**

Thesis submitted to the Portuguese Catholic University for the
Doctoral Degree in Science and Technologies of the Arts

by

Filipa Cordes Aniceto Martins de Abreu

ESCOLA DAS ARTES

(October 2019)



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Supervised by Prof. Doutor Álvaro Barbosa and
Co-Supervised by Prof. Doutor Carlos Sena Caires

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*For my daughter Gabriela.
Always be playful, creative and kind.*

ABSTRACT

This dissertation explores how the use of multimodal digital games can be implemented in the educational environment of Macau S.A.R., particularly in Kindergarten levels.

Today's children need innovative skills to be productive, and creativity and collaboration are two essential pillars in their learning development. Solutions involving technology can now form a bridge between Humans and their natural needs, through immersion in digital environments, which are vibrant with physical objects. Knowledge and information are changing rapidly, and digital interactive experiences are progressively being studied and used as tools to address several physical and emotional difficulties during the learning process. Humans grow by tackling necessary physical manipulations as part of their natural learning development.

During our research studies, we encouraged the use of digital games in school environments, and we encountered resistance when trying to establish the benefits of this practice, both in the teaching and learning environments. To overcome this challenge, we created and completed experimental studies in several schools, by introducing multimodal digital games in the three kindergarten levels of Macau's educational system.

With this in mind, we created a framework with multimodal experiences based on flexible design patterns that exploit essential visual, audio, and tangible elements. Children, from three to six years of age, learn and play through fun activities and subsequently trigger creative behaviors following User-Centered design approaches. We used out-of-the-shelf commercial game platforms (for learning) that have been implemented in learning environments and educational curriculums around the world. We gathered data from these studies, giving us insight into how children interact with digital devices and physical objects in a learning environment sparking the aforementioned creative behaviors.

We also confirmed that these platforms can have a significant impact on engagement when used in a collaborative environment and that creative behavior arises once freedom is given to children in a specific dynamic environment.

The collaborative engagement was observed and strongly supported when games were used in this context. When exposed to new exciting, fun, and challenging environments, children create different solutions for the task at hand.

The study leads to the conclusion that the cooperative and social nature of digital and tangible experiences is a vital and challenging behavior integrated into the learning development of a child. Multimodal and augmented reality interfaces combine both the digital and physical worlds to guide actions and behaviors, providing opportunities for users to develop new and old concepts and skills. Through game-based learning, at an early stage, children effectively develop their character and ideas by being exposed to new ways of interaction and physical flexibility.

The outcome of this doctoral research project resulted in a framework to support creativity in schools with multimodal digital games in learning environments. The said framework has User-Centered Design and Human-Computer Interaction for children, in consideration, as well as the incorporation of multimodal experiences based on flexible design patterns.

Our future work will consist of implementing a strategy for the large-scale application of this framework in schools in Macau S.A.R. and the encouragement of creative thinking in other more complex scenarios. Future game designs focused on multimodal digital games are also planned to be developed, having into account the findings of interactivity and creativity published in this Doctoral Thesis.

RESUMO

Esta tese explora como o uso de jogos digitais multimodais podem ser implementados numa atmosfera educativa em Macau, especificamente nos níveis de jardim de infância.

As crianças de hoje precisam de habilidades inovadoras para serem produtivas, e a criatividade e a colaboração são dois pilares essenciais no desenvolvimento da aprendizagem. As soluções que envolvem a tecnologia, podem formar uma ponte entre os seres humanos e suas necessidades naturais, através da imersão em ambientes digitais, que são empolgantes usando objectos físicos. O conhecimento e a informação estão a modificar-se rapidamente, e as experiências interativas digitais estão sendo progressivamente estudadas e usadas como ferramentas para lidar com várias dificuldades físicas e emocionais durante o processo de aprendizagem. Os seres humanos crescem enfrentando as manipulações físicas necessárias como parte do seu desenvolvimento natural de aprendizagem.

Durante os nossos estudos de investigação, incentivámos o uso de jogos digitais nos ambientes escolares e encontramos resistência ao tentar fundar os benefícios dessa prática, tanto nos ambientes de ensino como na aprendizagem. Para superar este desafio, criámos e concluímos estudos experimentais em várias escolas, introduzindo jogos digitais multimodais nos três níveis do jardim de infância do sistema educativo de Macau.

Tendo isto em mente, criámos uma estrutura de enquadramento com experiências multimodais baseadas em padrões de design flexíveis e que exploram elementos visuais, de áudio e de tangibilidade. Crianças dos três aos seis anos de idade aprendem e brincam através de actividades divertidas e, em seguida, desencadeiam comportamentos criativos seguindo abordagens de design centradas no usuário. Usámos plataformas de jogos comerciais (para a aprendizagem) que foram implementadas em ambientes de aprendizagem e currículos educacionais em todo o mundo. Reunimos através destes estudos, dados, adquirindo informações sobre como as crianças interagem com dispositivos digitais e objectos físicos num ambiente de aprendizagem, desencadeando comportamentos criativos como mencionados acima.

Confirmamos também, que estas plataformas podem ter um impacto significativo no seu empenho quando usadas num ambiente colaborativo, em que comportamentos criativos surgem quando a liberdade é dada às crianças num ambiente dinâmico específico.

O desempenho colaborativo foi observado e fortemente apoiado quando os jogos foram utilizados neste contexto. Quando expostos a ambientes novos, de desafio, de diversão, e de grande emoção, as crianças criam soluções diferentes para a tarefa em questão.

O estudo leva à conclusão de que a natureza cooperativa e social das experiências digitais e tangíveis é um comportamento vital e de grande desafio, integrado no desenvolvimento da aprendizagem de uma criança. As interfaces multimodais e de realidade aumentada combinam os mundos digital e físico para orientar acções e comportamentos, oferecendo oportunidades para os usuários desenvolverem novos e antigos conceitos e habilidades. Através da aprendizagem baseada em jogos, numa etapa inicial, as crianças desenvolvem efectivamente o seu carácter, e ideias, sendo expostas a novas formas de interacção e flexibilidade física.

O resultado deste projecto de investigação de doutoramento, resultou numa estrutura de enquadramento que visa a apoiar a criatividade nas escolas através de jogos digitais multimodais em ambientes de aprendizagem. Esta estrutura possui elementos de Design Centrado no Usuário e na Interação Humano-Computador para as crianças em consideração, bem como a incorporação de experiências multimodais baseadas em padrões de design flexíveis.

No futuro o nosso trabalho, consistirá na implementação de uma estratégia para a aplicação em larga escala, desta estrutura de enquadramento nas escolas de Macau e num incentivo ao pensamento criativo em outros cenários mais complexos. Também estão planeados futuros projectos de jogos focados em jogos digitais multimodais, levando em consideração os resultados da interatividade e da criatividade publicados nesta tese de doutoramento.

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DURING THE COURSE OF THIS DISSERTATION:

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- Creative Engagement: Multimodal digital games in children's learning environment in Macau S.A.R.
- 3D Printing Objects as Installation Art: "Standing Humanity: 3D Yan Character"
- Audience Participation in Interactive Art Systems: Is Instructional Signage a Necessary Evil?

MRI CONFERENCE - COMMON GOOD AND EDUCATION - CONFERENCE PAPER – 2017

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PRESENTATIONS

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Disclaimer

While, in the process, of writing, and after much consideration and deliberation, we decided to alter our original direction, the focus of the thesis changed from User-Generated games to Multimodal Digital games. Consequentially, we believe that there should be a title change, one that better fits this new orientation: **Multimodal Game Design Models: Fostering Creativity in Macau's Educational System.**

At the beginning of our research, we delved into user-generated game design/user-generated gameplay that is usually related to games that have content that has been created by the user, to add to the content made by the developer of that game. Not only are the players able to connect with other players through the creation of their specific and engaging levels and worlds, but also able to perform user-generated game design directly. User-Generated games are games that provide players the opportunity to create and manipulate the game world, develop their ideas, own points of view, and strategies within the game. By using the game developer's creation kit, players can create their own rules and mechanics as well as redesign their levels, sometimes even create their plug-ins to share with others.

User-generated game design has grown in recent years, and its popularity has developed quite fast, making the demand for new and engaging content, by its users, quite high, that is why this was so interesting for us to start our research. However, once we started researching these types of games, we soon realized that they did not suit our target audience. User-generated game design is known for its creation of tool kits created by programmers, artists, and game designers. These are useful for users/players/creators/game designers to create games within a particular specific game, modifying code, level mechanics, rules, gameplay, and create an even more remarkable thing, social collaboration.

Nevertheless, based on our target audience, we made a clear and solid choice, which was to research games that would provide our target audience with other types of experiences. Taking into consideration that children are still too young to create and modify games that are quite difficult for them to manipulate, based on their human development. So, we choose to stay with our target audiences instead of "User-Generated Game Design."

CHAPTER I

INTRODUCTION

CHAPTER I

1. Introduction

This research project was created as part of the *PhD program of Science and Technology of the Arts, with a specialization in Interactive Art*. This thesis focuses on the study and field-work related with multimodal digital games in education that bring the physical and digital worlds closer, with emphasis on kindergarten children.

1.1. Motivation and Problem Statement

The motivation for this thesis began when the author started studying video games at the master's degree level in Hong Kong. At a very young age, she would play video games at home, but it was when she found herself studying in Hong Kong that she discovered her passion for video games, not only playing them but creating them and being part of their essence as well. She was always fascinated by games and how we could engage and transform a classroom behavior and learning experience into something more relevant and fun for future generations. Since 2007, she has been involved with video games in one way or another, in production, design, or research. The area of game design for children is very dear to her, furthermore, with her professional background as a designer, researcher, and instructor, she tends to concentrate all her efforts on this subject. Games can be a powerful, meaningful tool for both teachers and learners. These tools, by themselves, do not have the power to revolutionize education, but in her points of view, they must be utilized in various meaningful ways in the learning environments. Nevertheless, studying games and/or making them with the purpose of teaching/learning is not always easy, and here is where the difficulty lies, making or using games meant for learning is an immense challenge.

However, having in consideration the different types of educational systems, curriculums, and learning situations, means that each learning environment has its own set of rules, but there are already schools in New York, Portugal and even in Macau S.A.R.¹ where digital games are already used as a basis for learning, demonstrating that they can be applied elsewhere. Culture, ways of thinking, language, policies, curriculums, laws, environments, experiences, play a great deal of importance in the use of digital games in the learning environment.

¹ Macau Special Administrative Region - "Autonomous region in the Pearl River Delta - China

Also, children nowadays learn and play in different ways, ways that we might not be used to or even understand.

Interaction design (UX) for children, for example, is a challenging, reasonably new, and future-oriented research field. In today's world, technology is developing extremely fast every year, especially everyday use technology, and children are introduced to these new interactive technologies and digital interfaces from a very young age, "even before they learn how to read, speak or even remember." (UIKE, s.d.)

Our research aims to promote awareness of what multimodal digital games are and how they can empower learning and foster creative behaviors in young children and how they can be implemented as part of the educational system in Macau S.A.R.

Taking into consideration digital games and creative behaviors in classrooms, we developed specific experimental studies where we observed diverse situations, not only children's user interfaces, behavior, or creative results. We had in consideration various theories on the overall psychological and physical development of a child.

Various theories helped us understand how digital games should be like and how they would adequately serve children's needs in a learning environment and what their possibilities and benefits are and how we can use them.

Presently, young children are drawn to the compelling world of screen-based technologies, such as mobile phones, tablets, and electronic games. Various educational entities around the world are focusing their curriculums and classroom settings, in-game design principles, and user-centered approaches to engage students in a class (Quest to Learn, s.d.).

These screen-based, multi-touch technologies and video games (Quest to Learn, s.d.) assist children in their learning processes by instantly giving direct feedback (Corbett, Anderson, n.d.) Nowadays, there is an immense learning strength in touch-screen devices and click-based laptop interfaces. However, children's development continues to be in permanent need of tangible interaction since 3D objects enable spatial thinking, development of excellent motor skills, and cognition. The capacity to touch, control, sense shapes, materials, and textures, in addition to the general notion of space and positioning,

is critical to children's growth (A. Antle, 2007). These skills cannot be acquired by 2D interfaces alone.

Nevertheless, as screen-based technologies are becoming so appealing for children, it is worth asking whether real-world interaction is still needed to enhance learning and enjoyment. Some have argued that these flat-screen technologies can have adverse effects on children (Cole, Suman, Director Phoebe Schramm, & Director Liuning Zhou, n.d.; Roe & Muijs, 1998).

Until this date, there is no research done concerning multimodal digital games for education focused on creative behaviors in Macau S.A.R., specifically for children. Degrees in Macau S.A.R. that provide Game Design or Game Development knowledge in this field are scarce, and it is seldom explored but important nonetheless for the development of the territory, being one of the most significant gaming areas in the world. Understanding the difference between gambling, video games, computer games, and digital games, and how games can improve and empower learning should be one of the focuses for this young and digital generation (The National Endowment for the Arts, s.d.) (kotaku, s.d.).

Digital game-based learning content and environments that provide learning opportunities to engage students in interactive experiences and that assist them in being part of the globalized technological society of the 21st Century are specific to modernized worlds. However, Macau S.A.R. is still not proving much in this area. But we would like to change that, increasing the research in this field.

1.2. Objectives

The objective of this thesis is to contribute to the field of Digital Games for Learning that focuses on creative behaviors in the Macau S.A.R, specifically by using multimodal digital games.

Building upon the hypothesis that multimodal digital games and game-design have unique characteristics introduced by the use of mobile devices as the facilitation devices for learning and creative thinking in the classroom.

More specifically, it is focuses on:

- Research of digital games for learning and how they can be adapted to Kindergarten levels and creative learning;
- We specifically focus on games that provide tangible and digital experiences.
- We focus on specific puzzle games. (Specifically block puzzles)
- We will research and implement design models related to User-Centered Design and Human-Computer Interaction for children in the learning environment.
- Creation of a framework for Kindergarten levels that use multimodal digital games in the learning environment.

1.3. Methodology

We have explored how tangible and multi-touch interfaces affect children's/user's performance, problem-solving, and creativity, for that a comparative experimental study was designed to collect quantitative and qualitative data by using digital/physical games and activities related to creative learning.

This research targets tangible and intangible mobile digital games being used in the learning environment of children in Macau S.A.R., taking into consideration learning and creativity to understand what is happening in the learning environment of young children and how can we further develop their learning situations with multimodal digital games.

In this research, two areas were explored, with the main focus on developing multimodal modules used in games to promote creativity through interactive interfaces.

The first area relates to what the audio and visual elements used in video games are — setting a guideline to create interactive environments for schools that want to increase and improve the creativity levels in the classroom.

The second area involves a more practical aspect of how interaction and creativity are interconnected with children's behaviors inside and outside of class so that students can learn to be more creative.

The goal is to develop a **MULTIMODAL DIGITAL GAME MODEL FRAMEWORK**. Using a theoretical analysis by using tangible user interfaces (TUIs) and multi-touch mobile devices. Its studies will be based on a more artistic-creative methodology by applying the use of audio and visual elements through a creative process combined with a thorough understanding of the theoretical context of how game design could be implemented in an educational environment and boost creativity. Various other elements will be explored, such as media, graphics, art, literature, creative methods, audio and visual modules, user interface design, and students'/players' interactions. Creativity, in its essence, is a process and has been analyzed with the aid of existing commercial games, and the influence these have on the learning environment of children bringing out creative behaviors.

1.4. Research Question

How can multimodal digital games be used in children's learning environments, specifically for fostering creative behaviors through user-centered design approaches?

Exploratory questions

How are game-design modules in games with learning content, relevant to education?

How can audio, visual, digital and tangible features in games be incorporated in education and intensify student/creativity?

How can multimodal digital games change the way educators instill creative behaviors in schools?

What are the characteristics of multimodal interactive and non-interactive digital games that are relevant to the creative process of a child?

1.5. Mixed Methods Research

This research has been the first of its kind in Macau S.A.R.'s schools, where children were the center of the study, and video games were the tool.

Experimental Study - Connecting the physical and digital worlds in a learning environment setting through classroom activities. Data was collected by recording and later analyzed. This data consists of questions, behaviors, and the evaluation of the digital/tangible games as well.

A questionnaire was conducted for each participant to support the experimental design.

1.6. Bibliographic Reviews

To answer the main research question, first, a literature review was undertaken by drawing on some core terminologies and principles while still leaving room for reflection and interpretation. To better organize the research, the main concern was to review literature that would fit in specific areas that would be related to the experimental studies that we conducted to implement the model. With that purpose in mind, we have divided the research into six main areas; Learning Environments, Social and Collaborative Content; Game Design, that includes gameplay, mechanics and rules; Multimodal Tangible User Interfaces, physical and digital information; Human-Computer Interaction, specifically for mobile devices, focusing on tablets and social usability.

1.6.1. Research Schematic

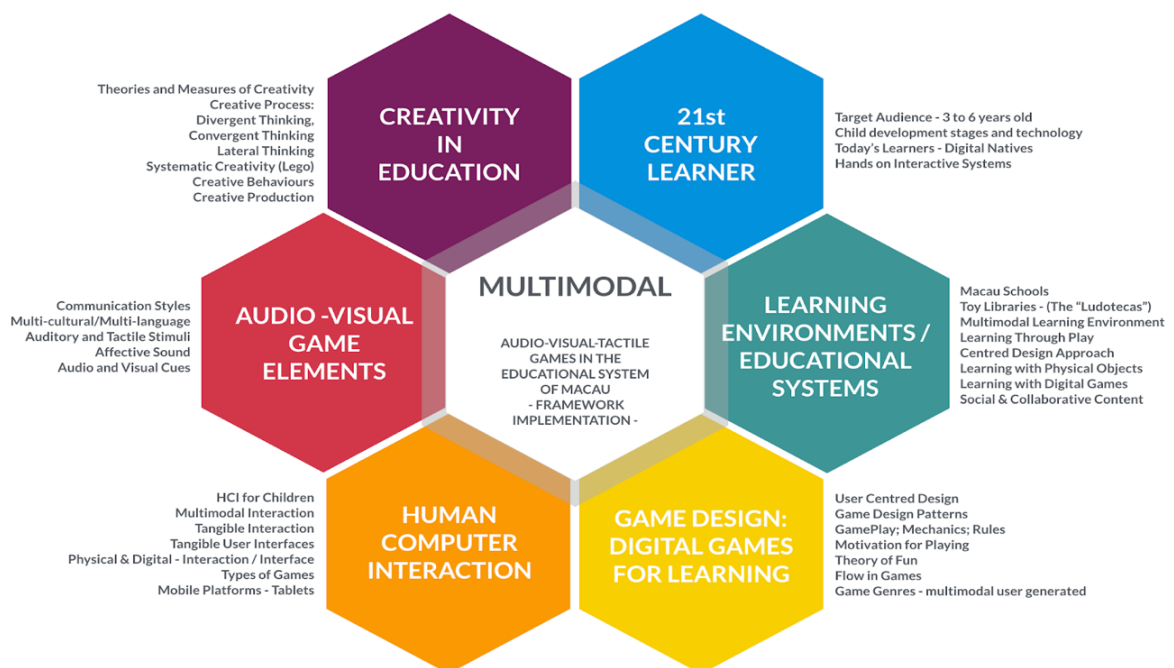


Figure 1 | This schematic covers the areas that were researched to complete this dissertation.

1.6.2. Research Strategy Processes

An academic literature search for a peer-reviewed journal and conference articles using databases such as Research Gate, Academia Digest; Springer, Association for Computing Machinery; Google Scholar where used.

In the first phase of the research studies, specific materials were included, relevant to the area being researched, helping on the overall structure and guidance of this dissertation. These readings focused on topics related to creativity in education, creative methods used currently in schools — audio and visual cues in digital and video game design that enhance the player's creativity. Audio and Visual strategies in video games and behavior modification, Game Design modules, Game Studies, User-Centered Design, Tangible Interfaces, in-home/public environments that boost creativity. Creativity in Education, User Generated Game Design – video games that use this feature to enhance the player's productivity engagement and creativity. Creativity and Behaviors, Interactive Interfaces, User Interfaces used video game design, Game Theories – specific for user-generated game design, and Creative Thinking.

The identification of experts working in the research fields mentioned above are: Piaget, Jean; Bruner; Prensky, Marc; Ogan, Amy; McGonigal, Jane; Zimmerman, Eric Bjork; Crawford, Chris; Lento, Eileen; Salen, Katie; Zin, Nor Azan Mat; Yue, Wong Seng; Jordà Sergi, Kulternbruner Martin; Collins, Karen, to name a few.

Books related to Game-Based Design, Game Design, Tangible Interaction, and Reports by various entities like Institute of play, Lego creative, are some of our references and will be mentioned in the Bibliography.

Library searches and google search related to books and websites that are important to the research and aid in understanding every strategy were used.

Careful research was undertaken related to the games that are used in education and that utilize manipulative and digital devices and multi-touch screens at the same time.

1.7. Scope of the Study

We explore how multimodal digital games can be used in children's learning environments, specifically by fostering creative behaviors through game design principles and user-centered design approaches. We made use of commercial digital games to understand and discuss the affordances of these games in an educational environment and how they support creativity in learning. We specifically used schools in the Macau S.A.R., a territory located in the People's Republic of China.

The goal of this research is to examine if specific digital games with tangible interfaces in learning environments have the potential to bring unified conditions of physical and digital interactions that engage children in learning activities and trigger creative behaviors. We specifically focused on digital mobile games that make use of both the physical world by using manipulatives that interact with the digital world.

We had a controlled and fixed group of children between three to six years of age, from Kindergarten levels one to three. We performed the fieldwork in three different schools of Macau S.A.R., one public based (government-controlled), another private, and the third one, mixed. We had to follow the school's regulations and guidelines to perform such experimental studies on their premises.

1.8. Thesis Outline

The organization of the following chapters is outlined below. The research conducted within this thesis project has been highly interdisciplinary. This requires the use of an extensive terminology set, borrowing terms from game studies, education, information systems, and instructional systems development.

Chapter 1 | This chapter is the introduction of the thesis, containing a motivational statement, the research question, the research schematic, bibliographic approach, methodology explanation, the scope of the study, and the thesis outline.

Chapter 2 | Provides a short survey background of games that were relevant to our research studies. These games utilized multi-touch mobile devices, audio, and visual elements, with a digital interface and using manipulatives.

Chapter 3 | This chapter provides the literature review. It is organized by; Target audience and the learner today, Typologies for learning, Digital Games for Learning, User-Centered Design Approaches, Physical and Digital Interactions, Audio-Visual Game Cues, and Creativity in Education. This section provides definitions of the most important and frequently used terms employed in this thesis.

Chapter 4 | This chapter explains the experimental design and study set-up. The logistics of the user study itself are addressed, including methods used for participant recruitment, trial assignment, and data recording measures and areas for evaluation.

Chapters 5 | This chapter mentions the descriptive analysis and presentation of the results of the study and exploration of the significance of those results. Additional charts and discussions are included to illustrate particularly relevant data, and statistical analysis is carried out in refutation or support of the central thesis question. Explanations are offered, and the Framework module is explained.

Chapter 6 | Covers the conclusions drawn from the data discussed in Chapter 5, as well as identifies the overall implications of this work mentioned in Chapters 4 and 5. Finally, areas for future work are suggested for advancing this project.

CHAPTER II

CONTEXTUALIZATION

CHAPTER II

2. Contextualization

“People of all ages play video games. There is no longer a ‘stereotype game player,’ but instead a game player could be your grandparents, your boss, or even your professor.”
(Jason Allaire, associate professor of psychology at North Carolina State University)

2.1. Ludic Activities & Games

Human beings have been playing games since the time of Ancient Egypt. A dice game named Senet, was played in Ancient Egypt as early as 3100 B.C., there was also the Royal Game of Ur, a board game, (Thompson, Berbank-Green, & Cusworth, 2007) and it was found in Archeological Excavations in the Middle East and it was dated from 2600 A.D. (Kilmer, 2009). These are only some examples that the first civilizations also played games and that games are crucial components of all cultures, and they have been one of the oldest ways of social interaction between civilizations. Ancient games have always been respected, and some of them are still played by many cultures. This shows that human beings have always made recreational activities part of their daily lives (Ana Maria Pessanha, 2018). Games are correlated with each other's cultures, and this is passed from generation to generation and becomes part of a traditional family trait.

Roger Caillois, a French game critic, mentions that playing games are considered a “waste of time” and resources but at the same time says that it’s an affirmation of “free will”, it’s a choice (Caillois, 1961; McGonigal, 1999).

For example, the Mahjong game, a Chinese tile-based game of the 18th century, is a traditional game played by many worldwide, Macau S.A.R. included. It is firmly rooted and part of the culture and traditions of any Chinese family.

Games are a traditional expression of play that allows people to go further than the instant imagination and physical interaction. The most seen feature of games has to do with the unpredictability of the outcome of the game, considering the mechanics and the rules of that game.

Human Beings always look for activities and challenges that provide the sensation of immersion and immediate satisfaction, Mihaly Csikszentmihalyi, considered to be one of

the co-founders of positive psychology, calls this the state of flow. The Flow theory is a well-established theory for examining experience in any setting and its application to game-play is intuitive (Cowley, Charles, Black, & Hickey, 2008).

“The best moments in our lives are not the passive, receptive, relaxing times . . . The best moments usually occur if a person’s body or mind is stretched to its limits in a voluntary effort to accomplish something difficult and worthwhile” (Csikszentmihalyi, 1988; “Quote by Mihaly Csikszentmihalyi: ‘Contrary to what we usually believe, moments li...”n.d.)

A few other features of a game are competitiveness, place, time, chance, fiction, predefined goals and personal enjoyment/fun.

In 1938 Johan Huizinga composed *“Homo Ludens”* (Thompson et al., 2007), a critical historical reference in game studies, which examines the importance of play in culture and society. Playing games as is described by Huizinga as *“Play is a voluntary activity or occupation executed within certain fixed limits of time and place, according to rules freely accepted but absolutely binding, having its aim in itself and accompanied by a feeling of tension, joy, and the consciousness that it is “different” from “ordinary life”.*” (Huizinga, n.d.; McGonigal, 1999; Thompson et al., 2007). Play for Huizinga was not part of whole thinking, however, Katie Salen and Eric Zimmerman, two-game makers and researchers took this a bit further in their book, *“Rules of Play”* (Salen & Zimmerman, 2004), which will be discussed in the third chapter.

From the 1970s to the mid-1980s, the first video games sprouted and the analyses in the fields of designing and researching regarding the area of sociology started to appear. There are a few analyses on the impacts of video games in children (Bandura, 1989), the disputable subject identified with viciousness in video games (Sherry, 2001) or its instructive potential (Malone, 1981).

Edutainment, Serious games and, gamification are essential in the field of the impact of video games on children.

The focus of video games will generally center around subjective researches, there are game designers, such as Chris Crawford, Juul, Katie Salen, Kelly McGonigal, and Eric

Zimmerman, who do a more profound comprehension of video games and their implications.

Video game players in but not restricted to the USA, range in every age, gender, and ethnicity. It does not matter where people are from, and it does not matter how old they are, what matters is the experience, the thrill and information they get from playing video games. These players live healthy lives, are civically engaged, and are socially active (ESA, 2019).

The revenue created by the game industry, rivals the USA film industry, suggesting that gaming appeals to more than just a niche market (ESA, 2009).

In 2018 it was a record-breaking year for the gaming industry, with video game deals surpassing \$43.4 billion (ESA, 2009).

Asia-Pacific has dominated the global video game market. In 2018, the income was estimated at 71.4 billion U.S. dollars. Compared with the North American gaming market it was twice the revenue (Video Game Industries in Asia, s.d.).

Around 164 million adults in the USA play computer games, and 75% of all Americans have, in any event one gamer in their family. It is by and by more critical than some other time in late memory to grasp who America's PC game players truly are and what is driving them, (ESA, 2019).

“...we are living in a brilliant period of computer games, and computer game players are flourishing.” (Essential-Facts-About-the-Computer-and-Video, s.d.)

Driving revenue aside, computer games have additionally formed and driven technology, research, and innovation. The game industry progresses rapidly, and games gradually become more multifaceted, making them hard to classify.

Gamers value game interfaces and only the best quality graphics will satiate their gameplay experience. “Quality of Graphics” is the second top influencer for purchasing a game, it counts for 63% of the reason (ESA, 2019).

Gamers are most often very demanding, not only with graphics but with physical technology that connects them to the game as well. These game accessories, i.e. game controllers, guitars, mats, glasses, aid in immersing the player in the game, and with continuous player demands, the gaming industry thrives. Experience is everything, and bringing novelties to this industry is what gamers desire. Every interface advancement produced for a game can conceivably link a considerable number of individuals. This makes an opportunity to broaden the interface and technology advancement. Consequently, games can and ought to be seen as an exploratory interface and gadgets testing ground (Pagulayan, Keeker, Wixon, Romero, & Fuller, n.d.).

2.2. Games Used in Education

For the past thirty years, chances are that most of us have played a game before, be it an educational game, a serious one or even a generic commercial game, whether it was required in school or played willingly at home with family. A lot has changed since the explosion of educational video games in the mid-80s, with new technology comes innovation, and with each year comes newer and better educational and/or commercial learning games for children.

The earliest game used for educational purposes was a computer programming game developed in 1970 by Seymour Papert and Wally Fuerzeig called *Logo*². *Logo* combined mathematics and programming by teaching players the basics of coding by directing a turtle-shaped cursor to draw lines.

A very dear game to various generations and that is still played in schools is Oregon Trail; it started to be used in education because it showed children the realities of 19th-century pioneer life on the Oregon Trail³ - 1971

Various games have already been studied and are still being used in educational environments around the world: Where in the World is Carmen Sandiego? -1985⁴ and Math Blaster - 1987⁵. There are a few other educational games that were unintentionally

² https://el.media.mit.edu/logo-foundation/what_is_logo/history.html

³ <http://www.hmco.com/at-home/featured-shops/the-learning-company/oregon-trail>

⁴ <https://www.amazon.com/Where-World-Carmen-Diego-Game/dp/B00DTHJBDI>

⁵ https://en.wikipedia.org/wiki/Math_Blaster!

academic, that are still acclaimed today, Civilization⁶ and SimCity⁷. In 1998 Star Wars droid-building game called Star Wars: Droidworks⁸, which used science as a factor. Whyville⁹, came out in 1999 and it was the first-person life-simulation education game to appear, you could customize your avatar, and this game set the standard for both online and life-simulator educational games. Although since 2011, there has been a game that revolutionized gameplay in the educational setting, which was Minecraft (History of Educational Games, s.d.).

But there are other games that have also been used in educational settings; Tetris, Sudoku, Brain Age, Portal, Hot Brain, Big Brain Academy, Little Big Planet, Spore, Drawn to life, Chemicus, Re-mission, Age of Mythology, Smarty Pants, Revolution, Mario's Time Machine, Pharaoh, Portal, Sims, Maps of the World, Why Ville, Angry Birds, Tiggly Shapes and Numbers, OSMO games and Cut the Rope.¹⁰

Not much is known on the effectiveness of these video games in modifying behavioral attitudes or health outcomes vs. conventional methods. Still, educational games are usually created by medical practitioners, teachers, and researchers that are not game designers, so they often develop products that miss out on the point - being fun. Students prefer commercial games as opposed to games specially designed for educational purposes (Bakar, Inal, & Cagiltay, 2006). So, the result is a game that looks great but flops due to the absence of immersion, simply put, the fun factor is not present.

But this is changing, numerous commercial games that are now being used in educational settings are having the input of teachers and research other than the other way around. The industry is changing so fast that collaboration between various studios and research labs are being developed and implemented around the world. This happens, for example, with the OSMO Learning Platform, where teachers have a lot of input and work together with the designers (Osmo Teacher Training, s.d.).

⁶ [https://en.wikipedia.org/wiki/Civilization_\(series\)](https://en.wikipedia.org/wiki/Civilization_(series))

⁷ <https://www.ea.com/en-gb/games/simcity>

⁸ https://en.wikipedia.org/wiki/Star_Wars:_Droid_Works

⁹ http://www.whyville.net/press/Real_Arguments_about_a_Virtual_Epidemic.pdf

¹⁰ <https://www.instituteofplay.org>

Because of this, new educational pedagogies have emerged that utilize game-based learning environments focusing on game design principles and play, which are progressively seen as tools for enjoying teaching and learning (J. J. Lee, 2010).

Going back to Minecraft, Minecraft Education¹¹ is an open platform game that promotes creativity, problem-solving and immersive environments that has the student as the center of it with collaboration being an additional asset that this platform provides.

Media Molecule¹² along with ConnectED¹³, a branch of Sony Computer Entertainment focused on the education sector, and it developed LittleBigPlanet2¹⁴ that is one of the kits used by teachers in the classroom. The theme for the kit will be the National Curriculum subjects. Physics, Maths, Science, Art, and History are all incorporated to help engage students in these subjects.

As Gee said, “gaming is all about learning a “new literacy” that can have beneficial applications in our development and our professional activities” (Buckingham & Burn, 2007) (Mackay, n.d.).

2.3. Types of Digital Games used in Learning Environments

Various games like Tetris, Puzzles, Sudoku, Brain Age, Portal, Hot Brain, Little Big Planet, Spore, Drawn to life, Chemicus, Re-mission, Age of Mythology, Smarty Pants, Revolution, Mario's Time Machine, SimCity, Pharaoh, Portal, Minecraft, Sims, Maps of the World, WhyVille, Angry Birds, Tiggly Shapes and Numbers, Osmo games, Cut the Rope, Minecraft Education¹⁵ and LittleBigPlanet2, have been studied and are being used in educational environments around the world.

¹¹ <https://education.minecraft.net>

¹² <http://www.mediamolecule.com>

¹³ http://www.mediamolecule.com/blog/article/fun_and_games_in_the_classroom

¹⁴ <https://littlebigplanet.playstation.com>

¹⁵ <https://education.minecraft.net>

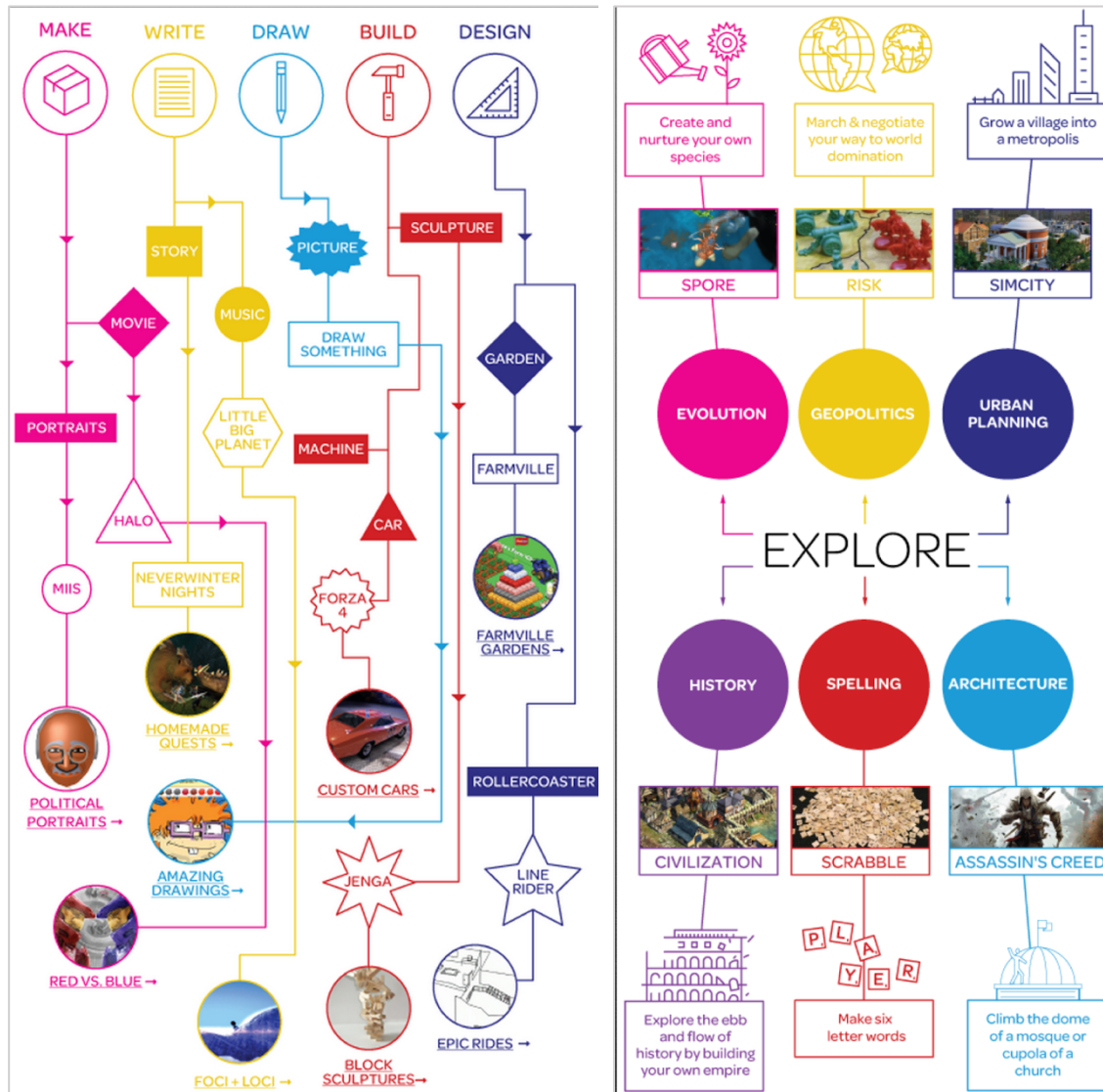


Figure 2 | Katie Salen, game designer, animator, educator and professor at the DePaul University College of Computing and Digital Media and Institute of play.

2.4. Types of Games and Toys we Researched | Definitions

Games

“game is a system in which players engage in a definite artificial conflict that ends with a quantifiable result” (Salen & Zimmerman, 2004)

“game is a form with objectives and structure” (Maroney, 2001)

“Chris Crawford mentions that any type of “interactive entertainment” is playable, alluding to books and films as non-intelligent inverse models, which nowadays even books and movies are interactive” (Crawford)

Toy Block Games

“Toy blocks, "building blocks," are solid shapes used for construction play. Some are simple planks made of wood. Others are fancy, like the interlocking bricks of plastic made by Lego and MegaBlox.” (Dewar, 2008-2018)

Puzzle Games

A puzzle is a game, issue, or toy that tests an individual's resourcefulness or information, the solver is relied upon to connect pieces in a specific way. There are various types of puzzles, for example, crossword puzzles, word-search puzzles, number puzzles, or logic puzzles. Puzzles are generally made to be a type of entertainment, to pass the time, yet they can likewise emerge from genuine numerical or calculated problems. In such cases, their answer might be a considerable influence in mathematical research.

Digital Games

“All games that have a digital technology base.” (DIGRA, s.d.)

Electronic Gaming

“Handheld game consoles, game consoles connected to a television, computer games online, computer games on a PC or CD ROM games.” (Encyclopedia Britannica, s.d.)

Video Games

“A term used by industry bodies such as Interactive Software Federation of Europe (ISFE) for television-linked consoles and portable video game systems. Video games are for the most part games that give varying media feedback to the player by means of a gadget, for example, a screen. Since video games utilize computerized pictures and not genuine items, possibly any shape or topic can be spoken to, from conceptual to sensible pictures.” (OFCOM)

Computer Games

Games played directly on a personal computer.

“computer games to a fine art in which players must oversee assets through components given by the game so as to accomplish an objective” (Costikyan, 1994).

Serious Games

“Serious games induce some kind of affective or motor learning (understood in a very broad sense) at any level. Put more simply: serious games are used for more than entertainment.” (Susi et al. 2007, Breuer & Bente, 2010)(IGI-Global, s.d.)

“There are various definitions about "Serious Games" but most definitions fall in this definition - Serious Games when are set in an educational environment target key curriculum areas for learning.” (Education Vic, s.d.)

Gamification

“Gamification is the application of game elements and digital game design techniques to non-game problems, such as business and social impact challenges.” (University of Pennsylvania – coursera)

Educational Games (Edutainment)

“Educational games are those intentionally designed for the purpose of education, or those entertainment games that have incidental or educational values. Educational games are designed to help people understand concepts, learn domain knowledge, and develop problem solving skills as they play games.” (Ge & Ifenthaler, 2018)

*“Computer-based electronic **games** with high **educational** value. They usually adhere to the constructivist theory of learning.”* (Ge & Ifenthaler, 2018)

Hybrid games

“A mixed reality game (or hybrid reality game) is a game which takes place in both reality and virtual reality simultaneously.” (Silva & Sutko, 2009; Bonsignore et al., 2012)

Mobile Games

“Mobile games are games designed for mobile devices, such as smartphones, feature phones, pocket PCs, personal digital assistants (PDA), tablet PCs and portable media players. Mobile games range from basic (like Snake on older Nokia phones) to sophisticated (3D and augmented reality games).” ... “Augmented reality games are the

latest mobile gaming trend. These programs combine a real-world environment with advanced computer graphics to provide the effect of augmented reality." (Techopedia Mobile Games, s.d.)

In our research, we focused on specific types of toys, games, and systems that are used in education or for educational purposes that use, physical objects (manipulatives), tangible user interfaces, table-tops and mobile digital platforms: audio and visual displays and cues. However, we started by presenting block toys that the children recognized and play with before. These toys all have a relation with the tangible and digital games and systems that will be shown later on.

Table 1: Specific types of toys, games, and systems that we focused on.



Toy Blocks (for education)

1594 - English writer and inventor Hugh Plat | Book: The Jewel House of Art and Nature.

1693 - English philosopher John Locke | Essay: Thoughts Concerning Education.

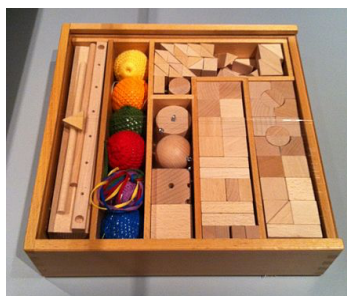
1798 - Maria and R.L Edgeworth's Practical Education. "Rational Toys Blocks"
Toy blocks (likewise fabricating blocks, building squares, or basically squares) are wooden, plastic, or foam pieces with various shapes (square, chamber, curve, triangle, cylinder, and so forth) and colors mainly used as development toys. Once in a while toy squares delineate letters of the alphabet as well as numbers. These toys are used all around schools in Macau, it does not matter what is the background of the children, school teachers or/and cultures...



1815 - 1820s

Tangram - 七巧板

Dissection puzzle /transformational puzzle - tiling puzzle –
Botermans, Jack, et al. The World of Games: Their Origins and History, How to Play Them, and How to Make Them (translation of Wereld vol spelletjes). New York: Facts on File, 1989. ISBN 0-8160-2184-8
<https://www.tangram-channel.com/tangram-puzzles>
<http://www.archimedes-lab.org/tangramagicus/pagetang1.html>



A reproduction set of Froebel gifts

1837

Froebel Gifts

"The Sonntagsblatt (1838-1840) published by Fröbel explained the meaning and described the use of each of his six initial "play gifts" (Spielgabe): "The active and creative, living and life producing being of each person, reveals itself in the creative instinct of the child. All human education is bound up in the quiet and conscientious nurture of this instinct of activity; and in the ability of the child, true to this instinct, to be active."

<http://froebelusa.com>

<http://www.friedrichfroebel.com>



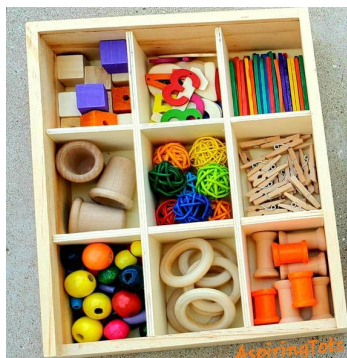
1923

Unit Blocks – bigger blocks than Froebel

"dramatic play – playing pretend"

Carrolina Pratt

<http://www.cpunitblocks.com>



Reggio Emilia



Wooden Sorting Box
Stack and Sort



Montessori System Manipulatives



Wooden Construction Building Blocks Bricks
Lewo



1949
LEGO
Ole Kirk Christiansen

"The LEGO System, as commonly understood, refers to the idea that any LEGO element, or any LEGO set, is not an isolated or complete object, but comes with the potential, and the promise, that it is part of a much larger whole. The system of interconnecting studs and tubes, patented by the LEGO Group in 1958"

<http://davidgauntlett.com/wp-content/uploads/2014/03/Gauntlett-LEGO-tool-for-thinking-chapter.pdf>
<https://seriousplaypro.com/2015/05/12/six-bricks-for-countless-exercises/>
<https://seriousplaypro.com/about/open-source>
<https://www.lego.com/>



1967
MEGA BLOKS
MATTEL
<https://www.megabloks.com/en-us>



1969
STICKLE BRICKS
Denys Fisher

"An individual stickle brick is a colorful plastic shape a few centimeters long which has a "brush" of small plastic "fingers" on one or more surfaces. The fingers of adjacent stickle bricks can interlock, allowing them to be joined in various ways. Standard sets of stickle bricks contain triangular, square and rectangular pieces. Many recent sets also include other types of pieces such as heads, wheels and teddy bear shapes."

Several companies manufacture similar toys, not all of them compatible. Names for these toys include "Nopper", "Bristle Blocks", "Fun Bricks", "Clipo", "Krinkles", "Multi-Fit", and "Thistle Blocks".



MAGNETIC BLOCKS



Picasso Tiles
3D COLOR MAGNETIC BUILDING BLOCK STEM SET
A Diamond Bar

“PicassoTiles is a fun “shape building” set utilizing embedded magnets that immerses children (and creative adults) into crafting 2D and 3D art sure to put a smile on those who appreciate creative, active learning.”

<https://www.picassotiles.com/>



2006
TEGU
Chris & Will Haughey

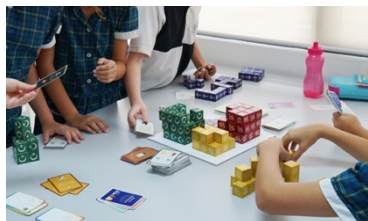
Tegu is a toy company based in Honduras and the United States that sells magnetic wooden toy blocks. The company was founded in 2006 by Chris Haughey and Will Haughey. The company aims to help Honduras through positive employment opportunities, tree-planting efforts, and by funding days of school.

<https://www.tegu.com/>



2017
Turkish wooden puzzle game.

<https://www.alamy.com/unidentified-children-play-a-traditional-turkish-wooden-puzzle-game-image151754941.html>



2017
Cultural Heritage Play

“Cultural Heritage Play is a tangible interactive board game project on the cultural heritage of Singapore.”

<https://culturalheritageplay.wordpress.com>

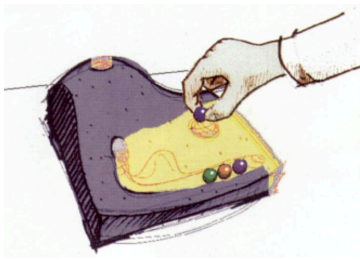


1988/1989
Mediablocks And Media Sequencer

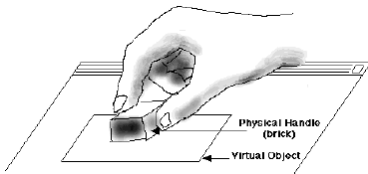
Brygg Ullmer, Dylan Glas, and Professor Hiroshi Ishii

MediaBlocks is a tangible user interface based upon small, electronically tagged wooden blocks. The blocks serve as physical icons ("phicons") for the containment, transport, and manipulation of online media. mediaBlocks interface with media input and output devices such as video cameras and projectors, allowing digital media to be rapidly "copied" from a media source and "pasted" into a media display. mediaBlocks are also compatible with traditional GUIs, providing seamless gateways between tangible and graphical interfaces. Finally, mediaBlocks act as physical "controls" in tangible interfaces for tasks such as sequencing collections of media elements.

<https://tangible.media.mit.edu/project/mediablocks>



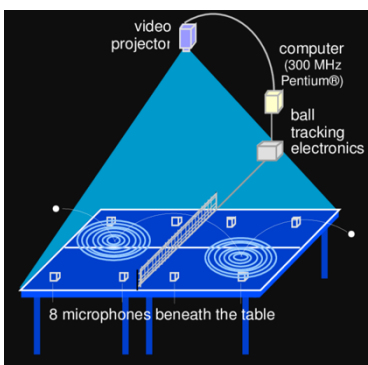
1992
Durrell Bishop | Student at the Royal College of Arts
Marble Answering Machine
"The machine spits out a marble each time an incoming voice message is recorded"
<http://dataphys.org/list/durrell-bishops-marble-answering-machine>



1994 - 1995
Fitzmaurice, Ishii & Buxton: Bricks | Graspable User Interfaces
"Graspable User Interfaces that allow direct control of electronic or virtual objects through physical handles for control" (Fitzmaurice, Ishii, & Buxton, 1995)
https://www.researchgate.net/publication/2491127_Bricks_Laying_the_Foundations_for_Graspable_User_Interfaces



1997
metaDesk
Hiroshi Ishii, Brygg Ullmer
"Tangible Bits allows users to "grasp & manipulate" bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces." (Ishii & Ullmer, 1997)
<https://tangible.media.mit.edu/project/metadesk>



1999
Wisneski, Orbanes, and Ishii, "PingPongPlus"; Ishii et al., "PingPongPlus."
"...concept of the "athletic-tangible interface," a new class of interaction which uses tangible objects and full-body motion in physical spaces with digital augmentation."
https://www.researchgate.net/publication/2312527_PingPongPlus_Design_of_an_Athletic-Tangible_Interface_for_Computer-Supported_Cooperative_Play

2002
Mandryk, Maranan, and Inkpen, "False Prophets."
(Mandryk & Maranan, 2002)
https://www.researchgate.net/publication/221517975_False_prophets_exploring_hybrid_boardvideo_games

2003
Magerkurth, Stenzel, and Prante, "Stars-a Ubiquitous Computing Platform for Computer Augmented Tabletop Games."
https://www.researchgate.net/publication/228825201_STARS-a_ubiquitous_computing_platform_for_computer_augmented_tabletop_games



2004

Augmenting the Virtual Domain with Physical and Social Elements
Magerkurth, Engelke, and Memisoglu

“A conceptual framework in which the relations between the virtual, the physical, and the social domains are modeled is presented.”(Magerkurth, Engelke, & Memisoglu, 2004)

https://www.researchgate.net/publication/220982541_Augmenting_the_virtual_domain_with_physical_and_social_elements_Towards_a_paradigm_shift_in_computer_entertainment_technology



2005

Pervasive Games
Magerkurth et al.

“The field of pervasive games is diverse in the approaches and technologies used to create new and exciting gaming experiences that profit by the blend of real and virtual game elements.”

https://www.researchgate.net/publication/220686485_Pervasive_games Bringing_computer_entertainment_back_to_the_real_world
<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.71.5879&rep=rep1&type=pdf>



2005

TARBoard
Lee, Woo, and Lee

“TARBoard which is a tangible augmented reality system designed for table-top game environment.”

https://www.researchgate.net/figure/Work-flow-of-TARBoard_fig2_216813679



2006

REACTABLE – TUIs

Sergi Jordà, Günter Geiger, Martin Kaltenbrunner and Marcos Alonso

The Reactable Experience is an innovative electronic musical instrument that enables everyone to experiment with sound, change its structure and be creative in a truly engaging, fun and visually appealing way, unlike anything you have ever known before. The perfect device for locations that are designed to captivate their visitors.

<https://reactable.com>

<http://www.synthtopia.com/content/2016/10/19/reactable-releases-rotor-tangible-modular-synth-for-ipad/>

2007

Frapolli, Hirsbrunner, and Lalanne, “Dynamic Rules.”

https://www.researchgate.net/publication/228810159_Dynamic_Rules_Towards_interactive_games_intelligence



2007

Tviews

Mazalek, Reynolds, and Davenport,

We have developed a tangible media table called TViews, which provides an extensible architecture to enable multiuser interactions with a range of media applications and content via tagged tangible objects.

https://www.researchgate.net/publication/4292101_The_TVIEWS_Table_in_the_Home



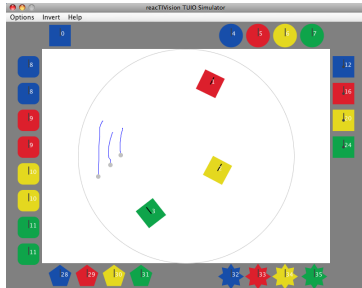
2008

Siftables

David Merrill And Jeevan Kalanithi
MIT Media Lab: Siftables

“Siftables were developed as a platform for hands-on interaction with digital information and media and were the prototype for Sifteo cubes”

<https://www.media.mit.edu/videos/labcast-20-siftables/>



2009
Reactivation/Tuio
Martin Kaltenbrunner and Ross Bencina

“reacTIVision is an open source, cross-platform computer vision framework for the fast and robust tracking of fiducial markers attached onto physical objects, as well as for multi-touch finger tracking.”

<http://reactivision.sourceforge.net>
<https://www.tuio.org/?processing>
https://www.researchgate.net/publication/221540139_reacTIVision_and_TUIO_a_tangible_tabletop_toolkit

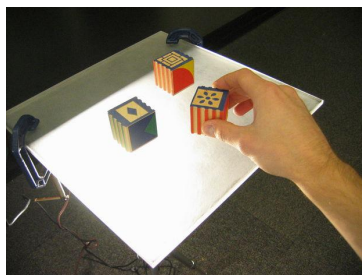
What people are doing with reactivation:
<https://vimeo.com/channels/reactivision/videos/page:7/sort:preset>



2009
Media Crate: tangible live media production interface
Tom Bartindale, Jonathan Hook and Patrick Olivier

“Tangible tabletop interface crafted in response to the key actions and needs of live media producers” “Tangibles that represent primary media icons”

https://www.researchgate.net/publication/221308720_Media_Crate_tangible_live_media_production_interface



2009
Trackmate
Adam Kumpf, Jean-Baptiste Labrune, Keywon Chung, Daniel Leithinger, Jamie Zigelbaum, Hiroshi Ishii

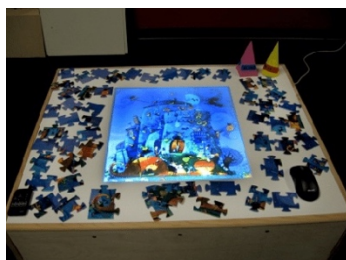
“Trackmate is an inexpensive, do-it-yourself tangible tracking system that allows your computer to recognize tagged objects and their corresponding position, rotation, and color information when placed on a surface. Trackmate sends all object data via LusidOSC (a protocol layer for unique spatial input devices), allowing any LusidOSC-based application to work with the system.”

<https://tangible.media.mit.edu/project/trackmate/>



2009
Touchtronic® Technology
“A Tale of Tangible Interactions: Junior Learning's Blended learning through educational toys, games and apps.”

<https://juniorlearning.wordpress.com/2014/06/03/a-tale-of-tangible-interactions-junior-learning-s-new-touchtronic-technology>



2009
The Eventtable
Alissa N. Antle, Nima Motamedi, Karen Tanenbaum, Zhen (Lesley) Xie

“The EventTable technique is a tangible object tracking technique implemented on a camera vision-based tabletop platform.”

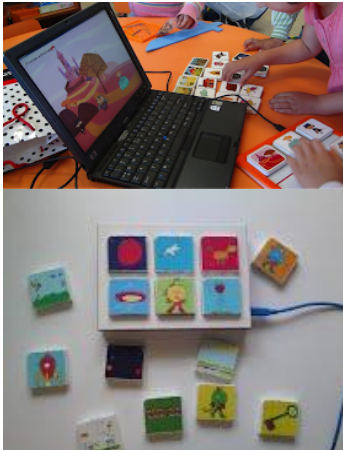
https://www.researchgate.net/figure/Tangible-jigsaw-puzzle-on-Figure-5-Tangible-concept-mapping_fig1_221308545



2010
Surface-Poker
Dang and André

“Multi-touch tabletop settings are conducive to co-located game play and foster interaction between players. People sit together face-to-face and interact not only with a computer system but also with each other via body or hand gesture, gaze, speech or aloud or the combination of those. A multimodal tabletop Poker game which makes use of both: additional interaction devices and physiological input data.”

https://www.researchgate.net/publication/220016372_Surface-poker_Multimodality_in_tabletop_games



2011
Tok - a tangible interface for storytelling.
Engage Lab

“TOK is a learning platform that mixes the physical and the digital experience enriching and expanding the way children learn”

<https://vimeo.com/33036567>

<https://sites.google.com/site/hybridlearningmaterials/home/projects>



2011
Sound Machine
Ramon Schreuder

“Interactive tabletop, on which people can create music together.”

<http://socialsoundmachine.com>

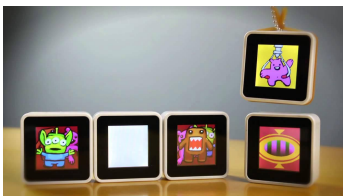


Figure 3. Animal toys used as Named Tokens (left). Reactivision fiducials used to identify them (right).

2012
Toyvision

“ToyVision”, a software toolkit aimed to make easy the prototyping of tangible games in visual based tabletop devices.

https://www.researchgate.net/publication/241770332_ToyVision_A_toolkit_for_prototyping_tabletop_tangible_games



2012
Sifteo Cubes
<https://www.sifteo.com>



2012
Wooden Crank Turns The
Ipad Into A Magical Music Box
Joel Aeschlimann
“The iPad's touch screen can be played by more instruments than just fingers.”
<https://www.fastcompany.com/1670389/wooden-crank-turns-the-ipad-into-a-magical-music-box>
<http://joelleaeschlimann.ch>



Smart Letters. Credit: Marie Meroze/Marbotic.

2012
Marbotic
Interactive Wooden Letters and numbers.
7 Educative Apps
<http://www.marbotic.fr>

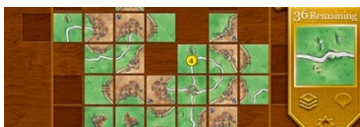


2012
Spellshot How To Play
“The Éditions Volumiques Are The Creators And Developers Of This New Type Of Games Combining Physical Object And Digital Tablet.”

Base For Pawn
Duguendungeon Crawling
Éditions Volumiques
<https://Vimeo.Com/51305421>
<https://Vimeo.Com/50058913>
<https://Vimeo.Com/50046643>



2012
Tower Defense
Éditions Volumiques
<https://vimeo.com/49924826>



2012
Johnson, “When Digital Versions of Board Games Surpass the Originals.”
“If video games and board games are cousins, then they are starting to behave like they belong to the European aristocracy. The two formats are intermixing such that the artificial line separating the two is blurring, with many digital games now built to resemble board games.”
https://www.gamasutra.com/view/news/180018/When_digital_versions_of_board_games_surpass_the_originals.php



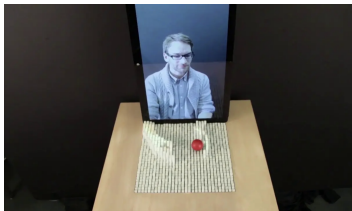
2013
Cuboino
“A tangible, digital extension for the marble-game Cuboro.”
<https://www.creativeapplications.net/objects/cuboino-is-a-tangible-digital-extension-for-the-marble-game-cuboro/>



2013
Explorers | Cards On The Tablet
DreamWorks (Kung Fu Panda, Shrek...)
Éditions Volumiques
<https://vimeo.com/74359492>



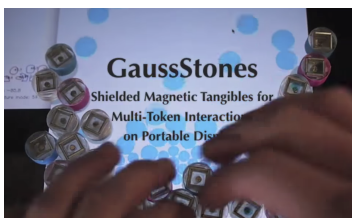
2013
Bridging Book
Ana Lúcia Pinto, Ana Carina Figueiredo, Pedro Branco, Eduarda Coquet, Ido Iurgel, Nelson Zagalo
<http://www.engagelab.org/projects/bridgingbook>



2013
inFORM
MIT Media Lab
“MIT has demonstrated a "Dynamic Shape Display" that can physically change shape to render 3D content. As Fast Company reports, the display is called inFORM, and it's a large surface that sits atop a series of pins, actuators, and linkages. ... MIT says it's exploring "a number of application domains" for inFORM.”
<https://tangible.media.mit.edu/projects>



2013
Tiggly Shapes
Educational Platform
<https://tiggly.com>



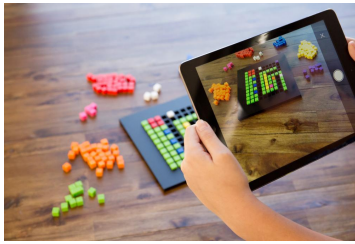
2014
Gauss Stones
Shielded Magnetic Tangibles for Multi-Token Interactions on Portable Displays
<http://www.cmlab.csie.ntu.edu.tw/~howieliang/GaussStones.html>



2014
Magikbee Smart Toys
“Classroom STEAM tool Magik play is a set of wooden building blocks that interact with an iPad in a series of puzzles and games. Merging physical and digital.”
Apple iPad STEM Learning Toys by Magikbee Smart Toys
<https://magikbee.com>

2014
Al Mahmud et al., “Designing and Evaluating the Tabletop Game Experience for Senior Citizens.”

[https://dragonlab.de/projects/thesis_hybrid_tabletop_games/Evaluating%20the%20Advantages%20of%20Physical%20and%20Digital%20Elements%20in%20Hybrid%20Tabletop%20Games%20\(by%20Tobias%20Wehrum\).pdf](https://dragonlab.de/projects/thesis_hybrid_tabletop_games/Evaluating%20the%20Advantages%20of%20Physical%20and%20Digital%20Elements%20in%20Hybrid%20Tabletop%20Games%20(by%20Tobias%20Wehrum).pdf)

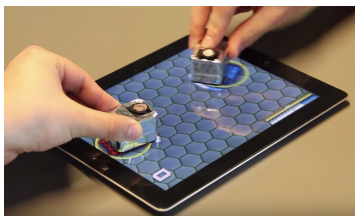


2015
Bloxel
<https://www.kickstarter.com/projects/pixelpress/bloxels-build-your-own-video-games-with-blocks>



2015
Legox
“[Lego X] is a network of bricks that communicate through an app made in-house,” Oluwaseyi Sosanya “You have your bricks and you start building with them; the system understands the shapes being built and lets you control certain parameters to modify the shape for use when finished building.”

<https://www.dezeen.com/2015/01/28/lego-x-gravity-digital-modelling-kit>
<https://creativepool.com/magazine/design/lego-x-is-3d-printing-in-reverse.4195>



2015
Medialogy - Tangible Widgets
Master's thesis project made by: Mads Bock, Martin Fisker and Kasper Fischer Topp

<https://www.youtube.com/watch?v=a3rwxnkyOQo>



2015
OSMO – Tangram

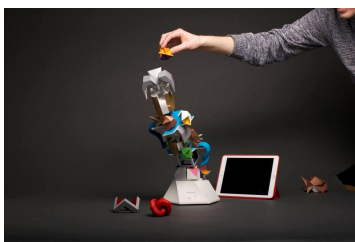
Tangible Play

<https://www.playosmo.com/en-gb>
<https://www.playosmo.com/en/tangram>



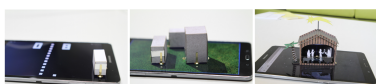
2015
Joujou Cube Touch
“Takara-Tomy's Joujou Cube Touch is an interactive digital toy for kids to learn while they play. Pick up the digital stamp cubes while touching the black panels on the side. Place these onto your iPad screen to interact with the colorful 2D world.”

<https://www.takaratomy.co.jp/products/joujou/cubetouch>



2015
Fabulous Beasts

<http://www.paper-video-games.com/blog/2015/06/30/fabulous-beasts>



2015
Paper Interactive

<http://www.makufunk.de/wp-content/papercite-data/pdf/wolf2015tuis.pdf>
<http://www.paper-video-games.com/blog>



2015
Onirigami
Studio Tourmaline - Marion Bareil And Camile Attard

<https://tourmaline-studio.com/fr>
<https://shakethatbutton.com/onirigami>



2015
La Fusée | Zéphyr
Éditions Volumiques

4 books
“The Éditions Volumiques are the creators and developers of this new type of games combining physical object and digital tablet.”

<https://vimeo.com/118038082>



2015
Kibo Robot Demo
Amanda Sullivan, Mollie Elkin, Marina Umaschi Bers

“Engaging young children in programming and engineering.” (Sullivan, Elkin, & Bers, n.d.)

<https://www.semanticscholar.org/paper/KIBO-robot-demo%3A-engaging-young-children-in-and-Sullivan-Elkin/24ab849ebdd408ad36c524e9d6cb4e7ac1c6c528>



2015
Project Legion

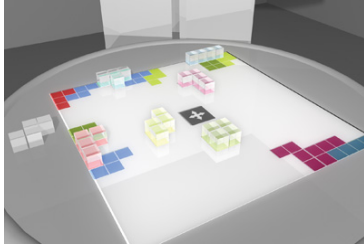
“Project legion is a board game that uses NFC tokens to play with a phone.”

<http://www.paper-video-games.com/blog/2015/08/31/project-legion/>



2015
“Game with a Tangible Tabletop Interface to Promote Student Engagement in a First Grade Classroom” (Kubicki, Pasco, & Arnaud, 2015)

<https://www.semanticscholar.org/paper/Using-a-Serious-Game-with-a-Tangible-Tabletop-to-in-Kubicki/4dfba25404f68e1ea2de4da9513c976906c1595b>



2015

Bachelor - Development of a tangible multiplayer Tetris game on a Multitouch Table

“Multiplayer - One, two or up to 4 players are able to play against each other or in cooperation on a multitouch table. Tangible 3d tokens are used for game playing, which have the shape of Tetris tokens should be used. A basic concept for the design exists already. This should be refined. New ideas can improve the concept.”

<http://campar.in.tum.de/Students/DaMultitouchTetris>

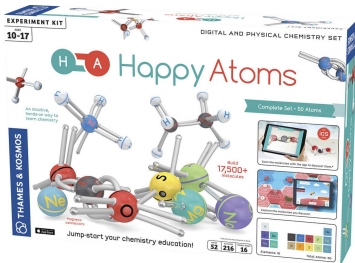


2015

Yibu - Smart Toy
Frog Design

<https://vimeo.com/frog>

<https://www.frogdesign.com/work/yibu>



2016

Happy Atoms
Jesse Schell of Schell Games - Happy Atoms at Schell's

“With this revolutionary approach to teaching chemistry, you can make your own happy atoms! This physical and digital system lets you discover the world of molecules in an intuitive, hands-on way.”

<https://www.schellgames.com/leadership/jesse-schell>

<https://www.wesa.fm/post/new-hybrid-digital-physical-games-may-improve-student-learning#stream/0>



2016

ROTOR - Ipad Pro

“ROTOR is the new app that turns your devices into a comprehensive electronic music performance suite. Using the optional ROTOR controllers, which can be purchased separately, it also brings the reactable tangible music experience that has captivated musicians such as Björk, Coldplay or Gui Boratto, for the first time into the iPad.”

<https://reactable.com/rotor>



2016

IQUBE
The Ultimate Toy for Learning Electronics

<https://www.indiegogo.com/projects/iqube-the-ultimate-toy-for-learning-electronics>

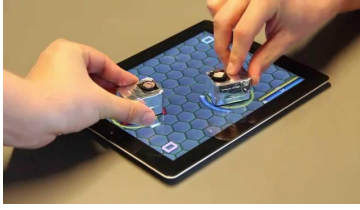


2016

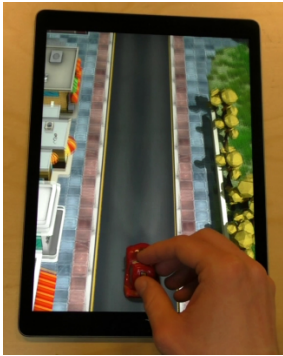
NORILLA
Nesra Yannier, Ph.D

“NoRILLA is a patented mixed-reality educational system bridging physical and virtual worlds to improve STEM learning.”

<https://www.norilla.com>



2016
Medialogy - Tangible Widgets
("Using Tangible Widgets for Travel in a Touch-Based Tablet Game with a Scrolling Camera - Project Library, Aalborg University," n.d.)
Benjamin Nicholas Overgaard, Gustav Dahl, Mathias Klitgaard Berthelsen



2016
Tangible Widgets for Travel
"A Touch-Based Tablet Game with a Scrolling Camera."

https://benjaminovergaardcom.files.wordpress.com/2016/05/tangiblewidgets_mta161036.pdf



2016
TAG-Games
Kiju Lee

"This video presents latest upgrades made on the TAG-Games technology that integrates music and sound into the game design."

<https://vimeo.com/164607729>
<https://case.edu/mae/robotics>



2016
Tangible Landscape
Anna Petrasova, Brendan Harmon, Vaclav Petras, Payam Tabrizian, & Helena Mitasoave

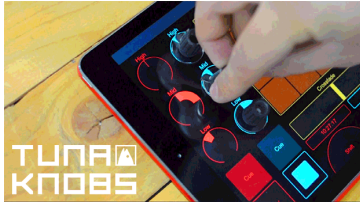
With Tangible Landscape you can hold a model of a Landscape in your hands, feeling the shape of the earth and sculpting its topography.

<http://baharmon.github.io/project/tangible-landscape>
<http://tangible-landscape.github.io>



2016/2017
Jimu Robot
"Building Jimu Robots"

<https://ubtrobot.com/collections/jimu-robots>



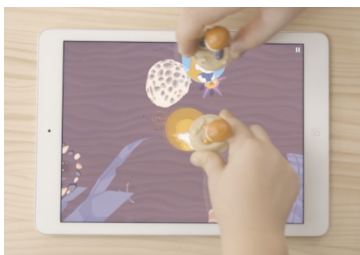
2017
iPad DJing With Knobs On!
Phil Morse

<https://www.digitaldjtips.com/2014/07/kickstarter-ipad-djing-knobs>



2017
Multi-Sensory
Storytelling Platform

<http://www.bearabouts.info>



2017
Oniri Islands

<http://oniri-game.co>



2017
Papertronics

<https://papertronics.org/en/projects>



2017
La Pluie À Midi
Story telling

Éditions Volumiques

<https://volumique.com/lapluie>



2017
Kids Coding
Ricardo Guzman

<https://www.ricardo-guzman.com/kids-coding>



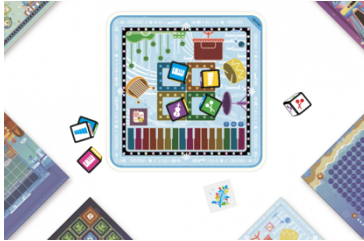
2017
Turkish wooden puzzle game.

<https://www.alamy.com/unidentified-children-play-a-traditional-turkish-wooden-puzzle-game-image151754941.html>



2017
Programación tangible

<https://www.youtube.com/watch?v=SX7Kdr1kOQM>
<https://www.youtube.com/channel/UCsrQkyzAUzvYEYI8twnm8rA>



2017
Beyond Tablet Games

Beyond Tablet is a large smart tablet without a display screen, and offers tangible interactivity with cards, blocks, and figurines, and a variety of fun and educational games for children and families.

<https://www.prlog.org/12611178-beyond-tablet-to-launch-tangible-game-suite-for-children-and-families-at-ces2017.html>



2017
Beyond Tablet

Beyond Tablet is a large smart tablet without a display screen. Children and families play Beyond Tablet games with physical game maps, cards, blocks, and figurines, placed on top of the object sensing and recognition surface of Beyond Tablet.

<http://www.beyondtablet.com/website/index.html>
<https://kapiawards.com/2018kapi/beyond-tablet/>



2017
Lego Boost

Lego wants to teach young kids about coding.

<https://fortune.com/2017/01/04/lego-ces-coding-kids/>



2018
Nintendo Labo

“A fun way to Make, Play, and Discover with Nintendo Switch. Build and play with cool creations and invent your own. Kits include everything you need—even games. Just add your Nintendo Switch console and go!”

<https://labo.nintendo.com>



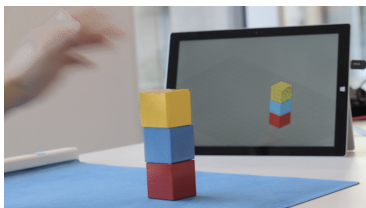
2018
MAKEBLOCK NEURON EXPLORER KIT

<https://www.makeblock.com/official-blog/220428.html>



2018
Sphero Specdrums Musical Rings

<https://www.apple.com/hk/shop/product/HMY42ZM/A/sphero-specdrums-musical-rings>



2018
Project Zanzibar

“Physical objects, identify what they are, and allow you to interact through multi-touch and hover gestures. Every object in the Project Zanzibar platform has a globally unique identifier (ID), which means data can be stored for each unique object.”

RESEARCH PROJECT MICROSOFT

<https://www.microsoft.com/en-us/research/project/project-zanzibar/>



2018
PAPER SAIL

<https://papersail.trestrescourt.com/papersail>
<https://papersail.lab.artetv>



2018
WOWCube

Ilya and Savva Osipov

WOWCube is a cube which consists of eight self-contained modules, which have 24 subdisplays collectively and rotate like elements of Rubik's Cube

<https://wowcube.com/>



2018
Tangible Engine

Tangible Engine enables users to take advantage of specially engineered physical objects that can be recognized by IDeum touch-enabled products.

<https://tangibleengine.com/>



2018
Oniri Islands

Camille Attard and Marion Bareil

The game reacts in real time to the presence of the toys put on the screen.

<https://mojo-nation.com/tourmaline-founders-talk-blending-tangible-digital-realms-islands-oniri/>
<https://www.tourmaline-studio.com/fr>



2018
Lomo

"LOMO is a colorful coding game introducing children to the world of logic. By using coding bricks - that light up with every step their robot moves - children decide where their adventure starts! No screen time is required!"

https://www.indiegogo.com/projects/lomo-the-tangible-coding-game/coming_soon
<https://www.prweb.com/releases/2018/06/prweb15533614.htm>



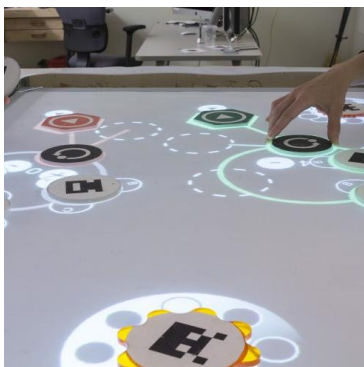
2018
Webee

The innovative Webee system was developed by parents and child educators who wanted to create a more stimulating alternative to passive TV and video entertainment for young children.

<https://shop-il.webee-world.com/>
<https://www.amazon.co.uk/Interactive-Educational-Video-Game-System/dp/B01KUYOYFM>



2018
Shifu Minglings and Shifu Safari Animals with Augmented Reality | Fun Educational Game Set | Mix & Match Magnet Wooden Toys for Children
<https://www.playshifu.com/gift>



2018
Tunetable
"Tunetable Is A Responsive Tabletop Application With A Tangible User Interface. The Intention Is To Teach Basic Computer Programming Concepts To Middle School-Aged And High School-Aged Students (9-16 Years Old) Using Physical Blocks That Work As Snippets Of Code."

<https://Dm.Lmc.Gatech.Edu/Adam-Lab-To-Demo-At-Steam3-Conference>



2019
Tei 2019 Work In Progress Demo:
“A Tui To Explore Cultural Heritage Repositories On The Web.”

Javier Pereda. Liverpool John Moores University

<https://new.eurekalert.org/multimedia/pub/193441.php>



2019
Mojobot

“Mojobot is a tangible coding robot and board game that makes it really easy for kids and adults to pick up and learn the core principles of coding and robotics. Mojobot is designed with both fun and educational value in mind.”

<https://www.kickstarter.com/projects/projectlab/mojobot-worlds-first-tangible-coding-robot-board-game>



Montessori Sensorial
Materials – Manipulatives

“Montessori Toys for ABC Learning | Smart Alphabet Blocks for Interactive Educational iPad Games for Preschool & Kindergarten | Learn English & Spanish | Toddlers & Kids 1-6 | Includes 5 Free Apps.”

<https://montessori.edokiacademy.com/en/catalog/creativity>



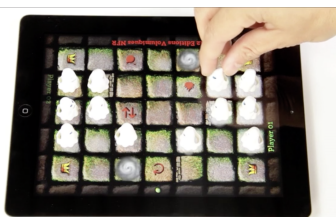
Under Development
Drag Drop – Educational
Gaming for Kids

<http://carstenhinz.de/work/dragdrop>



Merry Go Round
Engage Lab

<http://www.engagelab.org/projects>



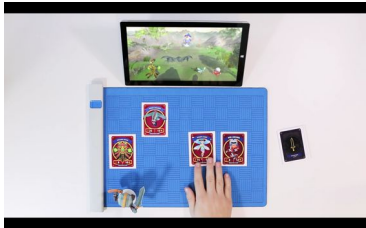
Éditions Volumiques

<https://volumique.com>



“Tangible Awareness: How Tangibles on Tabletops Influence Awareness of Each Other's Actions. Tangibles on multitouch tabletops increase speed, accuracy, and eyes-free operability for individual users, and verbal and behavioral social interaction among multiple users around smaller tables with a shared focus of attention.”

<https://www.youtube.com/watch?v=mFA6t-J6HRU>
<https://dl.acm.org/citation.cfm?doid=3173574.3173872>



<https://www.pinterest.com/pin/427208714646556598/>

Bakker et al., “Tangible Interaction in Tabletop Games.”
<http://www.elisevandenhoven.com/publications/bakker-ace07.pdf>

Magerkurth et al., “A Multimodal Interaction Framework for Pervasive Game Applications.”

“The system itself lists several possible input modes (table pawns, speech, table gestures, table WIMP and a PDA) and several output modes (table display, wall display, PDA display, loudspeaker audio and earphone audio) and details their capabilities and qualities.”

<https://pdfs.semanticscholar.org/5f88/7c7073c5702d092394b16e675f9daeab376a.pdf>

CHAPTER III

LITERATURE REVIEW

CHAPTER III

3. Literature Review

In today's technological/digital world, children require innovative skills to be productive, and creativity and collaboration are vital in achieving this. Solving problems through technology fills the gap between Humans and their needs. Information and knowledge are transforming quickly, and digital interactive experiences are studied while already being applied to combat physical, emotional, and common core issues during the learning stage. Humans evolve by approaching core physical manipulations as part of their natural development habitat.

3.1. Existing Research Based on Research Audiences // Ages Three to Six

As children grow, from infants to adults, they go through specific periods of development. These changes are both physical and psychological and are genetically proven, however, depending on the contextual environment, every child develops differently (Child Development Institute, Since 1999)

3.1.1. Child Development Stages and Technology

A child's learning development has three main stages (Fig. 3) starting with a motor response, moving on to visual information in the form of images/icons and finally reaching a state where children use words/language to express feelings, perceptions, and attitudes. Technology, (Fig. 4) on the other hand, has evolved in the opposite direction. It started with the use of text/language as a form of communication, followed by the development of graphical user interfaces (icons) and finally arriving at multi-touch, virtual worlds and augmented interactions, which are part of our lives today. Today's children need new innovative skills to be productive; creativity and collaboration are the two essential pillars in the learning development. Solutions involving technology can now form a bridge between Humans and their natural needs, through immersion in digital environments, vibrant with physical objects. Knowledge and information are changing rapidly, and digital interactive experiences are progressively being studied and used as tools to address several physical and emotional difficulties during the learning process. Humans grow by tackling necessary physical manipulations as part of their natural learning development.



1. motor response



2. visual information = image/icons



3. express feelings = words/language

HELLO!

Figure 3 | A child's learning development
(Bruner and Piaget - McLeod, S. A., 2008)



1. text/language as a form of communication



2. development of graphical user interfaces (icons)



3. multi-touch, virtual worlds and augmented interactions



Figure 4 | Technology development

Throughout the first eighteen months of life, children master control of their bodies, i.e., coordination, communication, and necessary emotional responses. Hence, from birth to the age of four, they undergo intense neurological transformations, they start to see, hear, feel, smell and taste the world around them, millions of new connections are forged in their brains each second. A person experiences the most rapid period of learning and development at that time, and it is the basis for the “*blueprint*” that will turn them into adults.

The cognitive development theories of children in early childhood are founded throughout the work of Jean Piaget and his constructivist theories (Piaget, 1962; Singer & Revenson, 1997). In Piaget's work, he identified that children progress through a series of cognitive development stages, as mentioned.

To understand this, a slightly better, we will talk about the development stages in more detail related to early childhood (Peirce, 2013).

Cognitive Development

Preoperational stage is where learning starts, which consists of a preoperational and intuitive sub-stage.

Preoperational stage: When the child develops away from egocentricity, and they cannot think logically, towards more social and collaborative learning. The inquisitive nature of the child at this age is a strong driving force of Curiosity.¹⁶

¹⁶

Intuitive sub-stage: When a child starts to draw conclusions founded mainly on impressions and perceptual decisions that are not put into words.

Psychomotor Development

During this period, children grow significantly in regards to musical coordination, active development, parity, and quality. The work of (Gallahue, Ozmun, & Goodway, 2012) puts a child of this age in the Fundamental Movement Stage. The Fundamental Movement Stage is portrayed by expanded control in discrete, sequential, and nonstop developments (e.g., running, bouncing, tossing, getting, bar strolling, and one-foot balance).

Social Emotional Development

A child's development is dominantly advanced through connections with their parents, siblings, family, and friends, work of (Erikson, 1980; James S. Fleming, 2004). The phases of most importance to early adolescence are that of Autonomy and Initiative.

Psychosexual Development

Psychosexual development of children in early childhood is dominated by the work of Sigmund Freud (Freud, 1970) and his work on the psychosexual stages of development. During this stage, the child becomes aware of the differences between boys and girls and more precisely, the genders of their parents.

A child can focus only on one object at a time, and this explains the impossibility of having any hierarchy for navigation. At five and six years of age, a child can recognize some words and write them down, but still, partial vocabulary is acquired. So, working with interfaces is still a bit limited when it comes to reading (Misa Kosa, n.d.) (Bruckman, Bandlow, & Forte, 2010).

When our objective is designing or studying children's behavior in games and interfaces we have to focus on several characteristics, Dexterity, Speech, Reading, Background knowledge and culture, Language and Interaction style (Bruckman et al., 2010).

3.1.2. Today's Learners

“Although there are multiple ways to unleash the creativity of individuals, schools still use the same norms and standards of teaching that they used decades ago.” (LEGO Foundation - Creating Creators, n.d.)

As technology evolves, economies fluctuate, populations change, so do values and behaviors. Education systems around the world, now have to struggle with massive outside influences of cultural change. Some of these are the direct features of digital culture Mark Prensky (Prensky, 2001b), and others make a distinction between digital natives and digital immigrants. When the 1980's generation, now in their 30s, was growing up, digital technology was in its infancy. The current generation of teenagers do not wear wristwatches to keep track of time, and nowadays, they wear them to receive messages and emails; there are apps that talk on a digital wristwatch. This shows that the proliferation of digital technology has created what is called *“the biggest generation gap since rock and roll,”* today, time is everywhere, on cell phones, tablets, smartwatches, etc. *“They see no need to wear a separate gadget just to tell the time”* (Robinson, 2011).

Sir. Ken Robinson states in his book, *“Out of our Minds: Learning to be Creative...”* children who are younger speak digital as their native tongue; for adults, digital is their second language. For our children, digital devices are not even considered technology. The natural sense of using digital devices is very reasonable is just like the *“air they breathe.”* If technology happens before we are born, is not technology, it is not new, it is old in their eyes.

Nowadays, children are always engaged with their digital devices. They multi-task much faster than adults, and they do it in a blink of an eye. For them, being connected and creating content is a daily routine. Before to access information and knowledge, older generations would have to go to school, and now we only need to be connected to the internet.

The ubiquity of digital technology alters the entire concept of education and the roles of teachers. In the last five decades, many of the old convictions have also broken down, the nuclear family, patterns of religious connection, gender roles, and much more. We live in a world in which cultural identities are multifaceted, intertwined, and disputed. The growing inequalities of wealth and opportunity are opening even deeper divisions between

cultural communities. In various countries, there is a worrying trend in disaffection, and aggression among young people in schools is increasing. Teachers and learners have different ways of communicating, and this is becoming more and more complex, and teachers are giving up (Robinson, 2011).

Getting younger generations in school engaged is a bit tricky; it is an issue everyone in the modern technological/digital world is facing. The world is moving towards a creative class that values conceptual knowledge and original thinking. However, the educational system is still educating children for the 19th century instead of the 21st century. In place of encouraging creativity, or thinking outside the box, and coloring outside the lines, we continue to instill in children new ways of memorizing information, even if that information is changing daily. A take away from this would be that we do not need to know facts, this is incorrect, we do; however, the power of knowledge comes from crafting those facts together in different and original ways, and circumstances and cultures are all different, so this has to be adaptable to all environments (Golinkoff, Hirsh-Pasek, & Singer, 2006).

3.1.3. The Player, The Creator, The Learner, (are all one).



Today's players have been creating their games with endless possibilities, taking both their imagination and creativity to higher levels. This occurs due to developers providing the opportunity of modifying the source code or even through creator kits, giving them the chance to create and modify the original gameplay, mechanics, and rules. Even the way fun is transmitted to other players is transformed. Social fun through social interaction, collaboration, and sharing is changing the way players play. Not only is it creating a more significant and broader engagement in the towards the game, but it also increases the lifespan of that game. This provides the gaming community with a broader set of tools, not only to be more inventive, but also to increase their creative behaviors.

Another thing that this kind of game experience can provide is a cost-effective research community as well as a development team to the industry. Games studies are a relatively recent academic discipline, and they examine why certain games inspire and are fun to play. Some approaches can provide intriguing insights for people designing and researching enjoyable user experiences.

Other approaches focus on the meaning and significance of the games to the looking at how games contribute to an understanding of oneself and other people and what the potential effects of games on social behavior are. Cultural, social, and contextual elements are crucial for the identification and creation of a user-generated game design. Play, create and share are the three main principles that, for example, Little Big Planet titles provided the game industry with, even if there have been many games that were already using these characteristics, but were not as evident. Not only are these elements available in this kind of methodology, but there is also a collaboration between users, which makes the player the center of game design. The player is what connects all these elements.

There is a big challenge when using games with children between the ages of three to six since there are limitations to what they can understand and do. Moreover, sometimes, the complexity of the tasks is difficult to achieve. That is why any game designer, teacher, or caregiver needs to be aware of what is happening to that child and how they are developing cognitively.

The challenge of using games with children of this specific age is that there are limitations to what they can understand and to the complexity of tasks that they can achieve. However, by examining how a child is changing cognitively at this age, it is possible to design games with understandable interfaces and develop appropriate learning content.

These are some of the things that we need to have when designing games for children; short attention span, low patience, long curriculums, different ways of learning, different cultural backgrounds. Most of the curriculums are not catching up to their expectations and are too long. New technologies, specifically mobile platforms and digital games, engage students through new experiences. However, not all teachers are equipped with knowledge that can take these technologies in the right direction. Because of this boom, teachers also have to be engaged in using these technologies.

3.2. Typologies for Learning Environments

“Today’s students are active learners rather than spectators.”

(Cynthia Luna Scott)

These last two decades have seen the rise of a worldwide development that requires another model of learning for the 21st century. There is currently a critical collection of writing concentrating mostly on three subjects – inspirations for another model of learning, the particular abilities and aptitudes expected to work successfully in the 21st century, and the teaching method required to animate those capacities. In many places, abilities and aptitudes were either not thought at all or not well thought out. Emerging worry about potential monetary and worldwide emergencies ahead is driving numerous to address whether the present students have the underlying reasoning, inventiveness, cooperative, and social skills that are essential to handle the unforeseen battles that they will have to face. Schools should take advantage of the new trends in this fast-passed world, and train their current instructors in order to fit in this technological world.

The advancement of 21st century abilities must not be deferred or held exclusively for higher-level understudies, and it should start at a very early age in education. Formal instruction and new social and technical abilities in our digital, technological, and fabrication revolution are changing daily, and learners have to acquire these new creative skills from the very beginning of instruction. It is known that formal instruction must be changed to empower the new types of learning needed to handle the complex worldwide of difficulties that are coming ahead. There is not only one way of dealing with teaching youngsters for the 21st century. New systems should open doors for learners to apply 21st century aptitudes crosswise over various territories, and this is likewise fundamental for more profound comprehension.

As mentioned by McLoughlin and Lee, 21st century supervision in learning environments depends on three instructive standards – personalization, interest, and profitability (McLoughlin & Lee, 2008). Learning should be done through legitimate and certifiable settings. Completing undertakings from start to finish, and taking care of issues as they emerge, all of which establish ground-breaking learning techniques. Cooperation, networks with educators, and friends is a beneficial learning encounter for students around the world (Bolstad, 2011). The 21st century instructional method must

utilize creativity and inquire about strengthened systems, learning advances, and certifiable applications (Saavedra & Darleen Opfer, 2012).

Learners are very much capable of gaining new skills when they assemble substantial metacognitive capacities, think about impartially new ideas learned, and coordinate that data with their current information and abilities.

The way toward adjusting new information for their very own utilization and fusing it into their current reasonable structures will mean further learning. When new learning strategies are implemented into existing “methods for learning,” this means that inventiveness and creativity are set in a new psychological mindset, which means that reasoning abilities are improved as well (Lai, 2011).

One of the biggest mechanisms for today's learning systems should be competency-based learning that joined with creative learning techniques use fortes, like, questioning, and issue-based methodologies that will improve a learner's abilities (P21, 2007a).

Nowadays, getting a Bachelor's degree that is strong enough for the demanding work environment, citizenship, and life in the 21st century is quite overwhelming. Globalization, new advancements in technology, accessible traveling, challenges, evolving markets, and transnational natural and political difficulties all drive the obtaining of new aptitudes and information required by understudies to endure and prevail in the 21st century. Teachers, trainers, governments, institutions and businesses, and analysis worldwide refer to these capacities as 21st century abilities, higher-request thinking aptitudes, more profound learning results, and complex reasoning and relational abilities.

Arguments concerning the capabilities and abilities students need to adapt to the unanticipated difficulties ahead have offered ascend to a critical assortment of writing. There is an unmistakable accord that new ways to deal with learning must oblige the qualities of the present understudies, become progressively comprehensive, and address 21st century interdisciplinary subjects. Personalization, cooperation, correspondence, casual learning, efficiency, and substance creation are vital to the abilities and aptitudes learners are required to create and how these abilities are educated. These components are essential to the overall vision in the learning of the 21st century (Carneiro, Crawford, & Goodman, 2007; McLoughlin & Lee, 2008; Redecker & Punie, 2014).

Individual abilities, social abilities, and learning aptitudes are crucial to crest execution in the 21st century working environment. While a significant number of these capabilities and aptitudes may appear to be current, they are not new (Scott, 2015).

3.2.1. Technology and games in Education

Technology in education is a complex topic, and it is not that straightforward or simple to incorporate, as many would have us believe. Technology has indeed brought various improvements to the way we teach and learn, but it also has transformed the way we interact and act around each other.

Although numerous technologies have been introduced in education over the years, with some even revolutionizing the way we work and collaborate, it is commonly accepted, that no significant changes in education have occurred (Howard & Mozejko, 2015). Technology is a powerful tool but can swing both ways; it can be used to inform or to mislead. So, while it can adequately inform, it can also provide information that might not be suitable for a particular age group.

Generally, when people talk about technology, the first thing they mention is computers. However, there are various kinds of technologies that can be used to improve learning and teaching. Digital technology is undoubtedly the most used means of teaching in an everyday classroom (Using Technology to Improve Achievement, 1999).

However, are they being used correctly, in their most effective way? This is a question researchers, policymakers, teachers, students, parents ask themselves many times. Is it? We will also take into consideration during our studies.

In the Macau S.A.R.¹⁷, for example, the government is promoting technology in schools by providing through their education department and funding entities, a lot of assets and materials that give the opportunity to teachers and students to engage in creative collaborations, science, design and thus promoting technology in education (DSEJ.gov.mo, 2007)¹⁸.

¹⁷ Macau Special Administrative Region - "Autonomous region in the Pearl River Delta - China

¹⁸ Funding - <http://www.dsej.gov.mo/fde/intro-e.html?timeis=Mon%20Jun%2004%2022:35:21%20GMT+08:00%202018&&> "to upgrade IT teaching facilities for the convenience of adopting diverse teaching methods"

This provides students and teachers with the right assets to the most up-to-date technology and incorporates it in the classroom and research environments, allowing students to use technology to create, research, collaborate, problem-solve, and interact worldwide.

Teachers, who were only seen as lecturers, now act more as coaches, they are facilitators, setting project goals and spending more time individualizing their instruction, providing students with personalized attention due to the nature of some technologies. By incorporating new technology and trying different things, the students see the world as a resource, and each one of them in charge of their destiny; this also provides them with increased alternatives and opportunities to explore and share information that would not occur in a traditional classroom.

Having technology and digital technologies in mind, let us revert the focus to digital games as another medium of instruction. Teachers are actively moving towards the use of digital/video games in the classroom to enhance their students' learning, however not all games are suitable to teach the common core areas like math and science (Felton, 2015; Emmanuel, 2015). In a game-based learning environment, games have to be specially designed with specific guidelines to meet individual educational requirements. Ensuring that schools are allowed not just access to computers but also the most updated technology, is essential (U.S. DEPARTMENT OF EDUCATION, n.d.).

Schools are using digital games as a significant a component of their learning environment, for example at Quest to Learn¹⁹, a digital school for children, students, improve their math, literacy, and problem-solving skills, by playing travel agents in the fictional Creep town game²⁰. Literacy, science, art, geography, history, mathematics, logic, communication, and creativity are all areas that are positively affected by utilizing digital games in learning environments (Sanford & Williamson, 2005).

Not all educational games have the desired effect that teachers and researchers would like, research studies based on frameworks have been created for the design and analysis of educational games by (Aleven, Myers, Easterday, & Ogan, 2010), where, with this framework in mind, they created a prototype of what educational games should consist of.

¹⁹ Public School Quest to Learn – game-based learning - <http://www.q2l.org>

²⁰ Free arcade game app.

Also, another framework for the design and integration of collaborative classroom games was created by (Echeverría et al., 2011). Both of these frameworks can assist in the design and integration of digital games in the classroom.

Due to the existence of new ways of teaching, new educational pedagogies have emerged that utilize game-based learning environments focusing on game design principles and play, which are progressively seen as tools for enjoying teaching and learning (J. J. Lee, 2010).

The use of digital games in education has been taking some of the attention away from conventional ways of teaching to new explorations on making games part of new learning environments in regards to game-based learning (Groff, Howells, & Cranmer, 2010).

Games allow individuals to collaborate as well as learn by playing and doing. Digital games provide them with instant feedback, demonstrating progression (losing or winning), which is different from conventional educational programs, suffering is part of the game. This becomes crucial to learn how to play it better, and how to play it again and again by getting acquainted with more knowledge. This motivation and this kind of play is essential for better learning experiences (Quest to Learn, s.d.)

The internet culture has transformed the computer and the way we communicate with each other (Bartleby, s.d.). The internet is seen as the “*world-wide broadcasting*” competency, it is a tool that assists with the distribution of information and connects everyone around the world independently of where they are geographically located. The internet connects everyone, everywhere, at any time, and students and teachers around the world have this great medium at their fingertips. Tablets, smartphones and computers have replaced textbooks, making the library the last place students go for information since the internet provides them swiftly with information, provided that the countries they live in have access²¹ to the internet.

There are numerous digital technologies that have a big impact in the way we learn, communicate and get information today, and the internet allows for that, in an easy and convenient way.

²¹ Number of Internet users - (https://en.wikipedia.org/wiki/List_of_countries_by_number_of_Internet_users)

Virtual Learning Environments (VLE), for example, provide e-learning²² education systems that are web-based, Blackboard Learn²³, Moodle²⁴, Google Classroom²⁵, Intranet Portals²⁶, are some of the flexible and easy to access tools that students and teachers can use in and out of any learning environment, you can find course assignments, grades, references, assessments and forums. Some of these tools even provide apps that are easier to operate, and that can be accessed through mobile devices, such as smartphones and tablet computers.

Adding to these environments are social media platforms and online virtual gaming communities that are extremely important for social communication and interaction between various people in specific niche groups.

3.2.2. Multimodal Learning

In order to talk a bit more about learning environments, we would like to explore multimodal learning environments. Most schools, Macau S.A.R. included, have distinctive learning styles, one learner may require a considerable number of visuals, while another could swap the visuals/image for any verbal clarification instead. Different learners need different data in numerous arrangements for ideas in order to understand what they are learning. That is why multimodal strategies that deal with this type of learning is ideal.

Multimodal learning in schools means training ideas in various styles. One of the most important things to understand is that we first need to comprehend the various learning styles.

Instructors should consolidate at least two multimodal learning modes to give a balanced instructive encounter. Since school situations have various understudy populaces with a wide assortment of learning styles, a multimodal approach enables every understudy to make scholastic progress in their particular manner. The learning styles are clustered together; they sort individuals by "style" of learning or adaptation. Each individual has an exciting learning inclination that falls into one of these classes below.

²² Online Learning - Distance Learning - MOOC's

²³ Virtual learning environment and course management system - <https://blackboard.com>

²⁴ Free open-source learning management system - <https://moodle.org>

²⁵ Google for schools - <http://classroom.google.com>

²⁶ Customized "gateway that unifies access to enterprise information and applications" - https://en.wikipedia.org/wiki/Intranet_portal

There are a couple of models to clarify the various learning styles. One of the most used is the VARK model, made by New Zealand educator, Neil Fleming.



Figure 5 | Kompas Muda | The VARK model of learning

Table 2 | Subsections of the VARK model

Visual	Auditory	Reading/Writing	Kinesthetic (sensations)
These individuals adapt best by observing/reacting to viewable prompts like pictures, diagrams, or outlines. They may be occupied by observing things outside.	These individuals adapt best by hearing/reacting to sound-related signs like verbal guidance, dialogs, or melodies. Outside commotions may occupy them.	This is, in some cases, recorded as a subsection of the visual class, yet the VARK model places it in its very own classification. These individuals adopt best by perusing and composing, reacting to composed signals like talk notes, books, and prompt cards. They may be diverted by inadequately worded content or content that does not coordinate discourse.	These individuals adapt best by doing/reacting to material signs like development, activities, and genuine models. Awkward seats or room temperatures may divert them.

Different learners have different learning styles, but many learners have more than one learning style, which makes them multimodal learners. Multimodal learners have a close equivalent inclination for various learning modes and can get a contribution from any of these modes (Fig. 6). Many multimodal learners have a unique learning style, and most often, they require various ways of learning. A multimodal learning style works mostly with numerous correspondence information sources, or modes. A multimodal learner will flourish in a learning condition that uses visual, sound-related, and sensation inputs, both verbal and non-verbal — also having in consideration, recordings, pictures, activities, genuine models, and hands-on exercises. Most learners enter a learning environment with various learning styles. Multimodality learning focuses on all styles of learning, and it is an all-inclusive structure for learning by imparting ideas in the best way and ensuring everyone gets what they require. Both content and sound backings are needed for these learners; pictures and movements can also help and focus their learning (Moreno & Mayer, 2007).

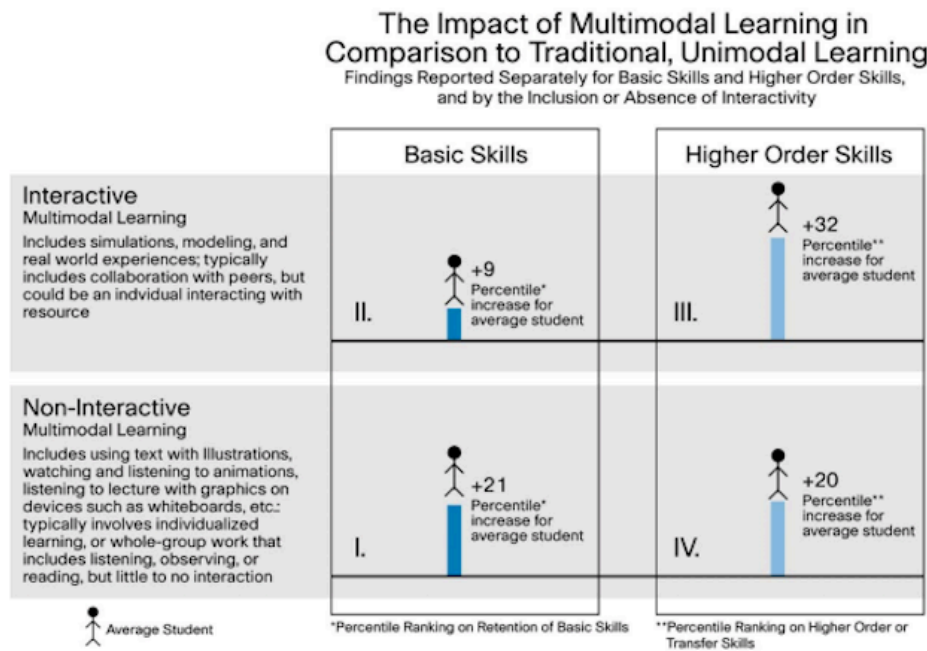


Figure 6 | Cisco - <https://www.prodigygame.com/blog/multimodal-learning>

3.2.2.1. Multimodal Interactive Learning Environments

An interactive multimodal learning environment is one that depends on the activities of the learner. A highpoint of intellect is characterized by the receptiveness of the learner's activity during learning.

Multimodal Interactive: Highly interactive — strong communication between the learner and the instructional system.

Multimodal Non-interactive: Linear, straightforward thinking that incorporates spoken and graphic images of the system to be learned. It does not allow for communication between the learner and the instructional system. The natural learning environment is usually non-interactive, the teacher gives the class, and the students listen and respond when asked.

Two types of learning views: Information acquisition and knowledge construction.

Information acquisition view - learning involves adding information to the learner's memory. The instructor's job is to present information, and the learner's job is to receive the information.

Multimodal mixed-modality learning environments are challenging to manage and to understand how to create them. They can sometimes be difficult because if not well organized and structured, they create disruptions in deep learning.

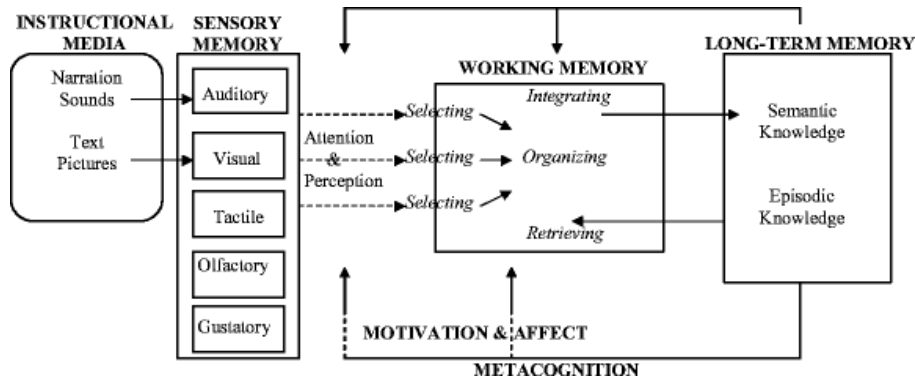


Figure 7 | (CATLM; Moreno 2005a) - A cognitive-affective model of learning with media.

(CATLM; Moreno 2005a) The cognitive-affective theory of learning with media created by Moreno and Mayer grows into the cognitive theory of multimedia learning (Mayer 2001, 2005a). Media like virtual reality, tangibles/digital games that focus on the virtual and digital worlds, present the learner an instructional asset that goes beyond words and images. Taking into consideration the CATLM theory, it is possible to develop cognitive principles of instructional design.

- “humans have separate channels for processing different information modalities (Baddeley 1992)”*
- “only a few pieces of information can be actively processed at any one time in working memory within each channel (Sweller 1999)”*
- “meaningful learning occurs when the learner spends conscious effort in cognitive processes such as selecting, organizing, and integrating new information with existing knowledge (Mayer and Moreno 2003)”*
- “long-term memory consists of a dynamic, evolving structure which holds both, a memory for past experiences and a memory for general domain knowledge (Tulving 1977)”*
- “motivational factors mediate learning by increasing or decreasing cognitive engagement (Pintrich 2003)”*
- “metacognitive factors mediate learning by regulating cognitive processing and affect (McGuinness 1990)”*
- “differences in learners' prior knowledge and abilities may affect how much is learned with specific media (Kalyuga et al. 2003; Moreno 2004; Moreno and Durn 2004)”*

(Moreno & Mayer, 2007)

3.2.3. Learning Through Play

Play is vital to children's mental health development, as it prepares them for school. It also offers them both social and cognitive advantages shaping their adulthood. A child's play is profoundly beneficial and provides a satisfying release when there is a working relationship with the teacher and their classmates (Golinkoff, Hirsh-Pasek, & Singer, n.d.).

Play originates from the connection among players, the arrangement of a game, and the setting where the game is played. Play and their relationships from young to adult enhance our social skills and feelings, and this helps us understand where we stand in the community and manage the pressures and doubts of life.

Skills usually arise through play, and become the foundations of happy and successful lives. Play is the engine behind human development. Children today are born in a society where digital technologies and new values, new ways of thinking, living, and working are quite different from thirty years ago.

Play in today's society has been reimagined as a dynamic, overlapping, frictionless experience that brings the real world, imaginary play, and digital experiences together as one. In uniting these play worlds across time and space, children today are mastering the art of finding new moments and forms of play, "*fluid play*" (LEGO ® Play Well Report 2018, n.d.).

Children's parents nowadays are also stressed to find time in their busy daily lives to play with them. Accessibility and facility to digital games and applications by the use of mobile phones, tablets, and computers allow children to extend their physical play experiences and with that creating memorable playful experiences.

These trends raise concerns amongst parents, who did not have much digital technology at a young age and had to learn later how to be digital, are afraid that screen time is displacing traditional physical play. Parents worry that technology makes the play, for children, a passive experience which decreases imagination and stops them from thinking for themselves. Technology isolates them from family and friends, and while these may be legitimate concerns, helping parents feel less anxious and more informed about the digital play is needed so that they can feel less anxious and more comfortable. Rather than being absent from their children's digital worlds, parents should help shape their play

experiences and balance their screen time with other forms of play. A more nuanced understanding of the role technology plays in the development of life skills, learning, and child development is a crucial phase in demystifying the digital layer in fluid play. “Sharing play is where the benefits come from” (LEGO ® Play Well Report 2018, n.d.).

“Play Makes People” (LEGO ® Play Well Report 2018, n.d.) supports learning and aids children grow and flourish.

Signs, signals, and noises are learned within playful imitation of those around them. Language is not taught to children but results from imitation of noises and movements they see adults doing. Additionally, they learn motor skills through long bouts of repetitive play, visualization, and hand-eye coordination play. Though necessary, these skills are the foundations for the accelerated growth that follows.

“Imagine a world in which children are encouraged to parrot answers, to fill in the blanks, and to not go beyond the facts. Imagine a world in which one size fits all (as in today's educational standards), and no size fits any.” Madeleine L'Engle (1962) describes just such a world in her classic book, *A Wrinkle in Time* (Golinkoff et al., n.d.).

From the home to the classroom, children are gradually programmed and controlled. As are the teachers who teach them, there is little time for play since all efforts are focused on memorizing *“facts,”* play is pushed aside to the second tier, as it is seen as a waste of time. Pressure on children in school is quite high, and inconsistently, their aptitude to reduce stress and have fun through play is limited (Golinkoff et al., n.d.).

Macau S.A.R., even though it is a territory that is open to new educational environments, is still a place where most schools consider the role of the teacher as the key holder of knowledge instead of being the facilitator. Very few schools have a different approach when it comes to the classroom learning environment. Some consider the classroom as a learning-by-doing approach with a very hands-on experiential methodology. The rest are still very focused on achieving the best scores by rote learning. These styles are the opposite of each other, but both contain positive qualities.

In most cases, with a learn-by-doing approach, parents, students, and teachers are more open to having video games as a learning tool both inside and outside the classroom. The apprehension of video games comes from associating that knowledge-seeking, will be

brushed aside in favor of the goal. Instead of finding content in knowledge, the completion of the game will take prominence. Another apprehension is that students will become more antisocial and/or violent by playing video games (Greitemeyer & Osswald, 2010).

Studies conducted by LEGO, on parents' beliefs about the play, in France, Germany, Great Britain, Japan, and the USA, shows that 94% of the parents believe that time consumed by playing is also learning (LEGO Learning Institute, 2002). *"Fisher-Price asked parents to rank the benefits of play, and they ranked "learning through play" at 12 out of 14, while "releasing energy" was at 1 (LEGO ® Play Well Report 2018, n.d.).*

For children with difficult life circumstances, emotional problems, or developmental delays, play maybe even more critical. Play is also critical to self-regulation, the foundation of choice and decision making, for mastery of higher cognitive processes, and morality (Golinkoff et al., 2006).

The role of play in pedagogy method, in the early years, is well documented, and there is sensible proof that by bringing increasingly "fun-loving" or "games-based" approaches into study halls, at all ages, can bolster the improvement of innovative abilities (Cumming, 2007)(Davies et al., 2013).

3.2.4. Meaningful Play

"Meaningful play in a game emerges from the relationship between player action and system outcome; it is the process by which a player takes action within the designed system of a game and the system responds to the action. The meaning of an action in a game resides in the relationship between action and outcome." (Salen & Zimmerman, 2004)

There is no specific date for the term *"meaningful play"* was created, however, it was first used in the area of video games, in the book *"rules of play"* by Katie Salen and Eric Zimmerman (Salen & Zimmerman, 2004).

In the book *"Rules of Play"* the authors divide meaningful play into two parts;

Discernable

"Discernable means that the result of the game action is communicated to the player in a perceivable way. In the following excerpt from Game Design: Theory and Practice,

Richard Rouse III points out the importance of displaying discernable information to the player within the context of the game world. Discernibility in a game lets the players know what happened when they took an action.” (Salen & Zimmerman, 2004)

Integrative

“Another component of meaningful play requires that the relationship between action and outcome is integrated into the larger context of the game. This means that an action a player takes not only has immediate significance in the game, but also affects the play experience at a later point in the game.” (Salen & Zimmerman, 2004)

Meaningful play is an activity where a particular purpose is integrated into the main activity, to gain knowledge, or to promote another purpose within that same activity.

There are various characteristics in games that aim at encouraging an active motivational meaningful playstyle outside and inside the game activity. Play originates from the relationship between players the way they play, and the setting where the game is played. Game designers are masters of engagement, and they create meaningful play experiences that have specific objectives of compelling gameplay. They master the principles of getting players, young and old, into virtual realities and getting them to succeed in meaningful ways, even having to face challenging tasks and failures by giving them moments of positively finishing exciting tasks. The good thing about games is that most of them provide adjustments dynamically, often to their players, with challenging puzzles that demand more acuity, quicker reaction times, and more ingenious solutions intelligence foresees if children in competitive environments will continue or give up (Dweck & Molden, 2005).

3.2.5. Free Play

“...play is really the way in which we explore the world.” (Scot Osterweil)

Free play is an amorphous activity that a child starts on its own, and it lets them develop their imagination when facing and exploring the world around them. This form of play is spontaneous, it comes naturally to every child, and it boosts their natural curiosity or their love of discovery (LEGO Foundation, n.d.).

Free play brings healthy cognitive development, the use of creativity and expansion of imagination, interaction with everything around them, development of social skills in

learning, decision-making skills, building confidence, resolve conflicts, and work collaboratively (Elena Malykhina, 2014).

Jean Piaget, in his book, *“Play, Dreams, and Imitation in Childhood,”* made the connection between play and intellectual, cognitive development. He outlined a progression of free play activities; functional, exploratory, and sensorimotor, to represent play as the child ages, which involved building with blocks and the imagining of taking care of a doll

(Play and Playground Encyclopedia, s.d.). He argued that play plays a role in a child's developing intellect and allows them to control their thoughts, behaviors, and emotions, with the outcome of learning to strive (Sandra Lynch, Pike, & à Beckett).

Friedrich Froebel, a German educationalist, was one of the pedagogues involved in the Kindergarten concept - *“Play is the work of children”* it is their “highest expression of what is in a child's soul (Froebel, 1826, 1887, p. 55).

Lev Vygotsky, a psychologist, claims that play is vital for children because they develop symbolic and linguistic abilities (Sandra Lynch, Pike, & à Beckett).

We believe that free play encourages children to develop their imagination further while using their creativity to come up with new innovative ideas. Playing with toys, that can only be used one way, and passive activities may not engage them in creative behaviors, that's why they need games that will give them a free play outcome (Play and Playground Encyclopedia, s.d.).

3.3. Learning with Digital Games

In a digital game-based learning (DGBL) environment, the approach of teaching with these games assist teachers in communicating the class content (Zin & Yue, 2009).

There still is a lot that can be done in the area of educational technology, a lack of research persists on how to design game environments that foster knowledge construction and deepen understanding in problem-solving, while engaging and entertaining the learner (Zin & Yue, 2009).

Learning outcomes need to be incorporated as a goal from the start of the design process, and pedagogy needs to be formally incorporated into games. In this paper, we reviewed the features of educational game design and history learning. Numerous digital technologies have a significant impact on the way we learn, communicate, and get information today. The internet allows for an easy and convenient way to operate. It can be accessed through mobile devices, such as smartphones and tablet computers. Adding to these environments are social media platforms and online virtual gaming communities that are extremely important for social communication and interaction between various people in specific niche groups.

Digital games have been used in educational environments around the world (Institute of Play, s.d.)²⁷. They are used in multiple fields as tools to teach math, politics, history, sharing, collaboration, multi-tasking, character development, hand-eye coordination, teamwork, creativity (Online Colleges Education), socialization, and citizenship (Quest to learn, s.d.). These game-based approaches engage students in tasks and activities that provide better learning experiences and produce better educational results. While not all educational games are successful, the influence of commercial digital games is increasing, and various teachers are using them in their teaching approaches (Groff et al., 2010).

If we focus on some online gaming communities for learning, we observe that they are entirely modifying the way players/students learn and interact, as well as how teachers teach.

²⁷ "Transforming education through play" - <https://www.instituteofplay.org>

Minecraft Education Edition (MEE)²⁸ is an open digital platform game that provides creativity, problem-solving in immersive environments and collaboration between students and teachers in and out of the classroom, it is revolutionizing education. When playing these game platforms, the players/students need the collaboration of others to fulfill some form of task, and schools empower this interaction and knowledge sharing. However, not all information given on these gaming or social platforms is “trustworthy,” so that is why in classrooms, for example, teachers have to work as moderators and selectors of information. MEE enables teachers to create customized lessons for students and work with them on their experience. Through the MEE online community, teachers can also share their experiences and classroom lessons that they have created with their students and share.

Media Molecule and ConnectED²⁹, a branch of Sony Computer Entertainment that focuses on the education sector, developed LittleBigPlanet2³⁰ (LPB), a game where you can create your games within games and customize your avatars. Teachers use it in schools because it incorporates Physics, Math, Science, Art, and History.

All these games either have a chat system incorporated or have forums where people can ask questions and interact with each other worldwide. All these social communities provide valuable and non-valuable information for learning; of course, teachers and parents have to be aware of these and guide students on what to do. Nevertheless, these social communities also work with teachers and schools so they can provide the best feedback and guidance possible. Major cities were the ones who benefited first from technology, eventually extending to the rural communities, but even today, in some more isolated areas of the world, this is still an issue as not everyone has an internet connection nor the technology at their disposal.

In the practical guide, “Transforming Education for the Next Generation, A Practical Guide to Learning and Teaching with Technology,” (Lento, n.d.) explains how digital technologies show their ability to empower educators when they work on the growth of the new generation of learners. The amount of research, creation, communication, and collaboration grows each day and provides a greater acquaintance with the world around

²⁸ “Vehicle for Learning” - <https://education.minecraft.net/how-it-works/in-the-classroom>

²⁹ Game Design and Developers - <https://www.mediamolecule.com>

³⁰ Little Big Planet game - <https://www.mediamolecule.com/games/littlebigplanet2>

them, opening their minds and increasing their skill sets to superior education and working environments (Elena Malykhina, 2014).

Video games are said to be the future of education (Quest to Learn, s.d.) since they play a significant role in school curriculums, they assist teachers in core teachings such as reading and mathematics as well as computer programming, helping students become engaged.

Many believe that gamification in education (Nolan & McBride, 2014) is also a reliable tool to get students involved and more active in class, by making learning more motivating. They also acquire new skills, aiding them in the success of their academic achievements and professional careers. The researcher, Scot Osterweil at Massachusetts Institute of Technology's Comparative Media Studies, believes that video games are crucial for learning. However, video games are only powerful tools if appropriately incorporated and should be paired with other activities and a guiding teacher. Many people question if students indeed gain anything by this, insisting that there is no proof of improvement or new skills being attained (Elena Malykhina, 2014).

Meeting the Common Core Standards has been the main goal for schools, for the last ten years, standardized testing has been the norm for recording a student's progress (Robinson & Aronica, 2016) This is not favorable to creative teaching methods, (Robinson & Aronica, 2016), that encompass video games into the learning environment. Moreover, standardized testing is becoming more and more negatively perceived in favor of creativity (Elena Malykhina, 2014).

With our experiments, we learned that students stay more engaged, focused, and when in groups, their reactions and actions differ from those when playing alone.

Researchers believe that “...*cross-cultural competency must learn through practice and training*” (Sadera, Li, Song, & Liu, 2014). This makes games a priority tool to know, for the skills of future learning. Researchers concentrate on both the positive and problematic aspects that contribute to assessing and developing games, focusing mainly on innovative behaviors to construct various ways of calculating creativity when playing a digital game. In our approach, we will be using off-the-shelf commercial digital games to understand how creativity is tackled in the learning environment (A. N. Antle, 2012).

"...education is not something which the teacher does, but that it is a natural process which develops spontaneously in the human being. It is not acquired by listening to words but in virtue of experiences in which the child acts on his environment. The teacher's task is not to talk, but to prepare and arrange a series of motives for cultural activity in a special environment made for the child."

(Maria Montessori, *The Absorbent Mind*, translated by Claude A. Claremont)

Digital games are increasingly being further considered to have a promising job in training forms. Highlights of games that could be connected to address the expanding interest for excellent training are now recognized as significant interests for learning. Clear objectives, exercises that can be polished over and over again until maxed, observing student progress, and modifying directions to student level of dominance — shutting the hole between what is discovered and its utilization, inspiration that energizes time on the undertaking, personalization of learning, and endless persistence. Furthermore, current computer games may create higher request thinking aptitudes, for example, critical thinking, vital reasoning, investigation, planning and executing, asset the executives, multi-tasking, and adjusting to changing work situations (Committee on Developments in the Science of Learning, 2000).

Explicit sorts of directions found in computer games strengthen successful learning standards and for the most part, improve learning results. Computer games animate substance changes in the part of the cerebrum that advances learning. Playing computer games stimulates dopamine discharge, a substance forerunner to the memory stockpiling process. Time spent on a task is another potential job of computer game in instruction. Convincing computer games that can convey instructive substance would expand the time spent on learning. In any case, look into studies are expected to propel games for learning. These examination studies need to decide the following: 1) how to configure learning games to convey positive learning results; 2) how to create devices to mechanize the way toward creating games for learning; 3) how to propose strategies and procedures to evaluate the information and aptitudes that students procure from instructive games (Jovanovic, Starcevic, Minovic, & Stavljanin, 2011).

Although many studies have explored the effects of digital game-based learning on learning and motivation, its benefits have never been steadily confirmed (Erhel & Jamet, 2013).

3.3.1. Flow in Games

Flow is an idea presented by Csikszentmihalyi (1998), who portrays the experience as the “*ideal experience*,” for example, the state where people feel so engaged in an activity that nothing else matters. The outcome from his investigation shows that individuals believe that what they truly need is the joy that meets up from the absorption in the undertaking.

A stream is an extraordinary encounter that can be arrived at when we are playing at any moment. Beforehand it has been utilized to portray the experience individuals accomplished from aesthetic exhibitions, playing sports, playing chess, and other numerous different exercises. A stream is a feeling that requires complete consideration and exceptional fixation while playing out a movement. It is comprised of a few different attributes, in particular: a harmony among test and ability, clear objectives, prompt criticism, consolidating activity and mindfulness, loss of hesitance, a feeling of control, time contortion, and encountering the action as inherently fulfilling (Csikszentmihalyi, 1998).

Game Flow is a model created by (Sweetser & Wyeth, 2005) intended to incorporate stream as a feature of the gaming information, even though it was progressively involved as a system to survey games as opposed to estimate experiences. It shows the highpoints of a game that are proposed to prompt stream encounters in video games. With stream as the fundamental principle establishment, the segments in Game Flow were mapped to stream parts to guarantee that the Game Flow model fitted into the stream hypothesis. (Sweetser & Wyeth, 2005) list the center segments in Game Flow as focus, challenge, abilities, control, a clear objective, criticism, drenching, and social collaboration.

Game Flow utilizes the hypothesis of a stream to distinguish, portray, and examine the components of video games. It isn't being utilized to clarify client encounters, which (Sweetser, Johnson, Ozdowska, & Wyeth, 2012) accept to be another kind of experience—not Game Flow, additionally, accept that a stream state is knowledgeable about a gaming session relied upon how the player identifies with the game as a movement. They accept that when gamers treat the gaming action as a significant action, they can accomplish stream. This is because the attributes of advanced games, that enable gamers to ace the game as the test creates, enable gamers to be invested in the action. The foundation of a Game Flow model that depends on the hypothesis of a stream is reasonable

as a structure to survey what an advanced game can offer as opposed to explaining what player experience is while playing a game (Csikszentmihalyi, n.d.).

“Creative individuals are rarely engaged in a single research thread or following a single train of thought. Instead, they ‘multi-task’. Any creative innovation, whether artistic or scientific, is “a loosely connected network of enterprises” (Csikszentmihályi, n.d.)

“The most creative people are those who are intrinsically motivated - they are so motivated by their work that they often find themselves losing track of time” (Dweck, 2006)

3.3.2. Immersion & Learning

Immersion in video games consists of a player being involved in the game, and it is easy to be immersed in a game if it has a compelling storyline, though not all games have the characteristic of immersion. A story that has multiple diverse paths aids the player in his interest, encountering different options, and countless experiences.

We can find two types of immersion in games, Impersonal immersion, and Personal immersion. There are more types of immersion if we deepen the study, but we will only focus on these two. The former is when a player is playing with a specific character that has a straight, consistent personality different from the player. The latter is when a player is wholly into the game, and the character represents the player by sharing his “personality,” emotional and behavioral responses. All this happens within a fictional context, and we can see this with Avatars and MMORPG games, where the player constructs the character in his image. These types of games involve open-ended storylines and even dialogue options between players. They can choose to interact with other players, role-playing in a multi-player environment, which gives them the chance to select and giving “feelings” to his/her avatar in the game. On the other hand, immersion in children tends to be more profound if the character looks exactly like they do (Mahar Ian, n.d.).

3.3.3. Socialization and Sharing

Education should be for everyone, and one's background should not be a factor. Through game-based learning, classrooms feel like social network communities where knowledge and skills are shared (Quest to Learn, s.d.).

Significant changes in the video game industry today, compared to twenty years ago, is that the social interaction and social collaboration inside the virtual/game environment are universal. To that extent, the so-called gamers and geeks are not socially unreachable, even when they spend all their time alone (Lenhart et al., 2008). Gamers are people who play with friends and family, collaboratively, or in a competitive environment (Entertainment Software Association, 2012). Examples of some of the games used for these social interactions are; Facebook games³¹, Farmville³², five million daily users in 2012, and/or MMORPGs.³³ An example can be World of Warcraft³⁴ that had twelve million regular players in 2012 (Entertainment Software Association, 2012). Other games that can also be found in this social environment is Little Big Planet, due to its user-generated content editor. Through this, gamers can create, share, and play collaboratively or alone by connecting with the LBPC Community³⁵ through the different video game consoles, namely Playstation 3/4³⁶.

These digital games act as virtual social communities where they have to interact with other players in real-time and have to make quick decisions which other players will have to either trust or reject, lead or be part of groups (Gentile & Gentile, 2008) (Gentile et al., 2009). All players in these communities have the same common interest, the immersive behavior in the virtual world. They are opened to new ways of engagement, earn new social skills and acquire positive behaviors (social acceptance, friendship) that, in a way, affects their families and relationships outside the game context (Gentile & Gentile, 2008) (Gentile et al., 2009).

Indispensable prosocial skills are acquired when players are rewarded by playing games that have a cooperative context; they encourage and aid others (Ewoldsen et al., 2012), (Hollingdale & Greitemeyer, 2014). A few studies have shown evidence that some of these games demonstrate prosocial behaviors (Gentile et al., 2009). There is also evidence that demonstrates that when played at the start of the school year, children are more likely to display useful behaviors by the end of the year. While this might lead to the conclusion that only nonviolent games with prosocial content result in prosocial behavior, there are

³¹ <https://www.facebook.com/games>

³² <https://www.facebook.com/FarmVille>

³³ 1990 - Massively Multiplayer Online Role-Playing Game.

³⁴ <https://worldofwarcraft.com/en-gb>

³⁵ <http://littlebigplanet.playstation.com/community>

³⁶ <http://littlebigplanet.playstation.com>

recent studies that show that violent games can easily promote prosocial behavior as well (Al., 1989).

3.3.4. Collaboration and Competitiveness

To distinguish violent and nonviolent games, components such as Competitiveness and Collaboration are essential. Players who play violent games cooperatively, show prosocial behavior instead of competitiveness and have also shown to display a friendlier behavior inside and outside the gaming environment (Jerabeck & Ferguson, 2013).

The cooperative and social nature of digital and tangible experiences is a vital and challenging behavior weaved into one's learning development (de Abreu & Barbosa, 2017). Actions and behaviors are steered by combining the digital and physical worlds with multimodal (Berti & Paternò, 2005) and augmented reality interfaces (Billinghurst, Kato, & Poupyrev, 2008), creating opportunities for learners to expand new/old concepts and skills. Young children are exposed to these new kinds of interactions and physical flexibilities in a game-based learning environment, allowing them to develop their character and ideas (de Abreu & Barbosa, 2017).

Therefore, playing in cooperation maximizes both prosocial and cooperative behaviors and improves relationships outside the game (Ewoldsen et al., 2012; Velez, Greitemeyer, Whitaker, Ewoldsen, & Bushman, 2014). Although these studies were mostly based on instant short-term results of cooperative play, long-term results also displayed potential benefits. This cooperative versus competitive gameplay produces social benefits, but for practice and policymakers, studies and assessments should be conducted long-term to provide a clearer picture (Granic, Lobel, & Engels, 2014). Another study (Lenhart et al., 2008) has shown that teenagers who played MMORPG, *Guild Wars 2*³⁷, (Civic Experience game) have better odds of being involved in outdoor activities, such as volunteer work and voting.

Presently, learning has become a joint effort instead of the more traditional teacher/professor method, co-creation, and open innovation are an essential aspect of the collaboration (Scott, 2015). There are three fundamental factors for collaborative learning, meaningful learning, intentional design, and collaboration of group members.

³⁷ <https://www.guildwars.com/en>

Collaborative learning has been studied mainly for its educational method, helping to comprehend collaboration between students and teachers. The goal is to achieve a better learning objective by pairing up or creating groups of students. By challenging students, they begin to trade ideas with peers, discuss different points of view, seek answers, and participate in higher-order thinking such as managing, organizing, critical analysis, problem-solving, creating new learning, and more in-depth understanding (Scott, 2015).

3.3.5. Negative and Positive Traits of Digital Games

In Macau S.A.R., explaining the benefits of digital games in teaching and learning environments can be quite an arduous task. In some schools, there is acceptance to new technology and new approaches, while in others, there is importance in finishing the curriculum on time with outstanding results. Although Macau S.A.R. is forthcoming to new educational environments, it still considers teachers as the keepers of knowledge instead of facilitators. Only a handful of schools have a different approach when it comes to the classroom learning environment. Some conservative parents still impart negative connotations to video/digital games, often associating them with gambling³⁸. The implementation of digital games in educational institutions is scarce, due to this, we are conducting studies to present the benefits by focusing on understanding how implementing commercial video games as tools for studying, contribute to a more productive education (Richard Sandford & Williamson, 2005).

The apprehension of video games comes from associating that knowledge-seeking will be brushed aside in favor of the goal, meaning that instead of finding content in knowledge, the completion of the game will take prominence. Another apprehension is that students will become more antisocial or violent by playing video games (Greitemeyer & Osswald, 2010).

However, there is enough information today to say that literacy, science, art, geography, history, mathematics, logic, communication, and creativity are areas that are positively affected by utilizing commercial games in learning environments (Richard Sandford & Williamson, 2005). There are various studies that focus on the negative aspects evoked by playing video games. However, children and teenagers live with video games as part of

³⁸ Playing for money.

their daily lives, in the USA, for example, at least 97% of boys and 94% of girls play video games regularly (McGonigal, 2011).

So, creating a more balanced strategy is needed, one that embraces the negatives and the positive aspects of video games. In the past decades, video games have been changing to better suit the needs of their players, making them more complex. They have a better quality of graphics, content, gameplay, and mechanics, and they are also becoming more realistic as they integrate more and more with their social lives. Significant research related to the gaming content has been emerging, and its benefits have been documented and are related to the cognitive, emotional, motivational, and social aspects of a player. These studies focus on assimilating various psychologies, on providing concrete evidence that games can provide mental health benefits (Granic et al., 2014).

3.3.6. Fun in Games

Technology has introduced many fun and innovative games that continuously provide novel challenges. Fun is one of the most significant and most enjoyable characteristics of most video games. They not only demand players' specific goals and a certain amount of skills but also assess the effectiveness, in fun ways, of how they play and interact with the game while providing feedback.

Many studies emphasize on uncovering experiences evoked by playing digital games (Granic et al., 2014). While games can be fun and cause positive emotions, there is an unexplored area regarding the consequences of positive emotional experiences during video gameplay. Playing games makes people happier, which seems to be a crucial emotional benefit to consider. Experiencing self-assured feelings is a conscious inspiration that precedes play. Nevertheless, this is not enough for games to be implemented as tools for education. (Granic et al., 2014).

Video games can be designed to improve the development of creativity while retaining the fun value. They are offering a new generation of games that will eventually blur the lines between education and entertainment. Much work is focused on investigating the potentials (Nacke & Lindley, 2010) definition and limitations of immersion, motivation, perception, and emotion in digital games. One of the challenges of studying them is trying to define their true meaning.

However, playing games is often considered a relaxing activity, and gaming environments may nurture a tenacious, positive motivational style. This clear motivational style could reform schools and work frameworks. Players need to have designers that are sensitive and aware of their needs to be knowledgeable about the usability of concerns and be more rigorous in calculating how to create learning environments with audio and visual elements that will help the players improve their behaviors.

It is vital to understand and study the degree in which turning to video games to feel happy and improve behaviors is what is necessary, and at what point using games becomes an evident strategy that may lead to less adverse outcomes.

3.4. User Centered-Design / Game Design

User-centered Design (UCD) is a widely-used term that was first used by Don Norman around the 1980s and became extensively used by various designers, researchers, and technologists to explain design processes. UCD has the user, who influences and contributes to defining the product's identity, as the center of the design. The designer's primary focus is the user's needs, wants, and limitations. Users are different, opinions, and definitions of the same product differ, so that is why testing the usability of a product is key for developing the right product for the right user.

When we design interfaces with children in mind, especially with learning difficulties, we must have UCD principles in mind in order to have the right design product. Not only usability tests are essential, but also the user's involvement in the design process of such a product. A designer cannot only be intuitive and do what he likes, and he/she needs to base his/her ideas on design principles in order to have a coherent and refined product (Abrás, Maloney-Krichmar, & Preece, 2004).

“A positive User Experience results when the goals of the user and the organization that created the product are met” (Scout Stevenson (user-experience) – (Harvard i-lab | UX Design: An introduction)

When it comes to an understanding of the types of experiences educational games can provide, and how they can be tied to learning objectives, game design research is especially influential.

Game study researchers have discussed that video game design has to reach the desired level of complexity and creativity, and it is vital to develop the right set of conceptual gameplay tools. Having into consideration this goal of developing and implementing methodologies and techniques to formalize the conceptual game design tools, these need to be more concise by creating classifications accepted by some researches.

Iterative UCD must be considered when we want any game being developed by us to be as appropriate and useful for students as possible. It is essential to involve them in evaluation throughout the design and development process. The process of iterative user-centered design supports this user participation at diverse phases and allows us, as designers, to get ongoing feedback so that we can identify problems early and adjust the

game design and interface as required. UCD is of serious significance in the design of computer systems in general and games in specific, particularly in the design of games for learning, where players that interact with the game can seriously affect the type and level of learning they are in. The essential significance of UCD includes putting its users at the center of the software design process and looking at how they use and interact with the software and systems that are being developed (Robertson, Jepson, Macvean, & Gray, 2016).

Most concerned questions related to these experiences are traditional usability methodologies being replaced by new usability methodologies seen in-game research, and its primary concerns are increasingly related to enjoyment, gratification, options, and fun. These new methodologies and analyses that are being developed with a focus on the elements of gratification and social interactions use the concept of social usability, which has been incorporated in games that possess the content creation tool component (Bruckman et al., 2010).

UCD principles and participatory design have increased the views, and the habits of the user, and consequently, the design focusses on that process. When talking about innovation, the focus lies in the importance of observing real-life situations, which in turn urges for methods that allow the user to be the center of production practices. It is seen in academic approach readings, business-oriented consulting, and strategies. Commonly, we tend to focus on the mechanical elements of games, but in reality, what makes a game is not the actions that the system provides to the player, but what the player does with them. These are mechanical systems created for a Human, so systems have to have Human characteristics and physiological considerations as the center of their design. For those users, simple modules are crucial for the understanding of the psychological behaviors of a game. Usually, the user is an individual driven by both their conscience and unconscious mind to learn a new set of skills with a high-perceived value. By successfully acquiring these skills achieves a high degree of enjoyment (Daniel Cook, s.d.), (Bernhaupt, n.d.).

3.4.1. Design Considerations for Games

Current educational research has focused on how people learn by playing digital games and less work focused on what and how children learn with game design approaches and serious digital creation (Thumlert, de Castell, & Jenson, 2018).

Having into consideration the target research audience and their development stages, we should reflect on a few elements for the design of games for the educational environment.

Concerning the children's intellectual/cognitive development, we should consider a few things related to interfaces:

- **Simple, clean interfaces**
- **Little use of text**
- **Stress-free interface components**
- **The use of visual symbols should be used with caution because of interpretation.**
- **The use of language and audio cues should be precise and not subject to misunderstanding.**
- **Background culture is also important.**
- **The role of the teacher/parent should be significant when playing with the child.**
- **The role of the parent/teacher in play is significant and should be accommodated (NCCA, 2004).**
- **The use of language should be encouraged to discuss problems.**
- **The use of overly complex tasks can cause children to revert to more straightforward thinking strategies (Gage & Berliner, 1998).**
- **The development pace is not uniform across all children and is affected by experience, culture, and heredity.**

(Thumlert et al., 2018), (Peirce, n.d.).

3.4.2. The Mechanics-Dynamics-Aesthetics Framework | MDA

The main difference between any type of game and other entertainment products, like music, books, films, and plays, is that their use is somewhat random. The thread of events that occur during gameplay and the outcome of those events usually is unknown at the time of the finished product.

Mechanics-Dynamics-Aesthetics (MDA) framework was created by (Hunicke, Leblanc, & Zubek, n.d.) This framework attempts to describe the effects that specific consumption of games has on players' experiences by breaking it by diverse mechanisms. It is an approach to understanding games, filling the hole found in game design/development, game criticism, and technical game research (Hunicke et al., n.d.). Studies in game design

center on how specific elements and mechanics of games; their rules, goals, narrative, and fiction are designed, and how they affect the play experience.

Mechanics, Dynamics, and Aesthetics are three words that have been used unofficially for a long time labeling numerous types of games. However, the MDA framework gives us specific meanings for these terms and tries to correlate them to each other and how they influence the player's experience.

M - Mechanics - basic components of a game. Basic rules, actions the player can take in the game, the algorithms, and the data structures in the game engine...

D - Dynamics - Run-time performance of the mechanics depended on the player's input "cooperating" with other mechanics.

A - Aesthetics - The emotional response the player induces.

What is essential about this framework is the idea that games are more like relics than media — denoting that the content of a game is its comportment, not the media that comes out of it, specifically at the player. So, by viewing games as relics, it helps structure them as arrangements that shape performance by interactions. It backs stronger design specificities and studies at all levels of design and development (Hunicke et al., n.d.).

3.4.3. Games for Entertainment and Games for Learning

One of the things to consider when applying an existing game for learning is to contemplate how a digital game designed for entertainment differs from a game that was designed for learning. These differences are varied, devotion, quality of graphics, game performance, awareness of the game, time to complete the game, cooperation, and competition within the game will also differ significantly between games (Whitton, 2010).

Although extensive studies have been done to detail and map out the internal structure of educational games as "game products," studies to understand them as objects in a context of use are few. Schools or classrooms are not empty receptacles which can be filled by educational games. Furthermore, a game's impact is not only determined on how well it balances subject matter representation with concepts of good game design. The context is essential, and it includes aspects that put limitations on what an educational game is

“allowed” to do, but also elements that can ease play sessions and lessen some of the pressures of what educational games need to convey through their design (Simon Egenfeldt-Nielsen, Jonas Heide Smith, 2010).

There need to be better educational game studies, a deeper exploration in examining the realities of using games as teaching tools. Creating good educational games is more than design choices that develop the dynamics between the game and the player or even a balance between engagement and learning ideologies, it needs to include formal education as a context of use. Bogost describes the basic notion of educational games as “massive rejection of the customs of both video games and education.” ... If we want to have educational video games, we are using games against the grain, and education against the grain”. Studying formal contexts requires concerns in how we think about gameplay and game design, and also how we think about educational practice and organization (Bogost, 2008; Egenfeldt-Nielsen, 2011). The formal context is not always a compelling factor; it provides several unique opportunities that might create new types of gaming scenarios and ecosystems. The studies conducted in this thesis attempt to focus on that information gap by providing some examples of why it is problematic and negatively affects educators and developers (Simon Egenfeldt-Nielsen, Jonas Heide Smith, 2010).

3.4.4. Spatial Problem Solving - spatial environment³⁹.

Problem-solving is a difficult skill to succumb to, depending on the nature of the problem; it involves different cognitive processes. It involves divergent thinking, convergent thinking, spatial reasoning, visual search, mental visualization, and justification, as well as metacognitive processes and non-cognitive variables

Domain-specific problems, it also involves conceptual reasoning. Spatial problem solving is related to problems in which the spatial characteristics of a problem are essential to plausible solutions.

Space features that may be important to the problem on-hand for a child include object location, shapes, sizes, positions, orientation, proximity, grouping, or other spatial relationships.

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Spatial problems that may be encountered by children include puzzles, mazes, simplified geographic, urban, ecological, or biological planning problems; architectural, engineering, or structural transportation problems; geometric modeling; and organizing one's bedroom! Research is needed to understand the role of hands-on interaction in spatial problem solving, what kinds of behaviors are most productive, and how to design interfaces that support these behaviors (Committee on Developments in the Science of Learning, 2000).

3.5. Physical and Digital Interactions

Over the past years, the amount of time children spend on a computer has tripled (Kaiser Family Foundation research). So, we took into consideration, in our experimental studies, not only the children's use of technologies and interfaces but also our interest in theories on the overall psychological and physical development of the child. This helped us understand what the user experience and interface design should be, ensuring that all needs are served and considered all expectations for a child (Bruckman et al., 2010).

When designing interfaces for children, we cannot assume that they are creative, intelligent, and capable of great things. Studies show that Piaget underestimated children's cognitive abilities and that through assisted interaction with the physical world, they can learn and solve problems in certain fields physically before they can express them verbally, demonstrating that sensory-motor activity is crucial to cognitive development. Alongside Piaget, Dewey⁴⁰, Froebel, Montessori⁴¹, as well as Papert⁴², also share this view in the pedagogical "hands-on" traditions, that intelligent behavior stems from engaging with physical surroundings (A. N. Antle, 2012).

Screen-based games likewise have potential inspirational advantages, for example, convincing situations and connecting with characters. Then again, most characteristic learning occurs in our physical 3D world, and some oppose this notion. The physical world can enable kids to play, find, test, and learn in their natural world and do as such in a manner that likewise bolsters social cooperation (Gros, 2007).

Without a doubt, numerous past innovation endeavors have urged children to play with physical artifacts, for example, building squares and riddles to gain proficiency with various aptitudes (O'Malley, Fraser, & Others, 2004). Notably, in science spaces, children's' perceptions of changes in their natural physical condition may promptly help them make more disclosures and creating a comprehension of essential science standards. Combining the benefits of the physical condition and computer advancements, substantial interfaces and blended-reality circumstances may enable understudies to learn in more attractive and unusual ways than "either approach alone" (Thumlert et al., 2018).

3.5.1. Multimodal / Human Computer Interaction

⁴⁰ John Dewey was an American philosopher and psychologist.

⁴¹ Maria Montessori – Montessori Methods.

⁴² Seymour Aubrey Papert - South African-born American computer scientist, educator, mathematician.

Human-Computer Interaction (HCI) field, specifically video games and public/home interactive experiences, are progressively being studied and are used as tools for explaining and answering several social problems in and out of the educational environment. HCI is a field of study that started focusing on the design of computer technology and, more precisely, the interaction between computers and humans but has expanded to cover nearly all types of information technology design.

At three to six years of age, a child's motor skills are not yet developed enough, so the central role of technology and user experience (UX) is played by large pictures, instant visual and audio feedback, and understanding the total lack of user patience (Mila Kosa, s.d.).

HCI has lately had some profound changes. The focal point of research has shifted from undertakings to activities, from workplaces to the boulevards and the home, from labs to settings where individuals invest their energy and from essential "ease of use" to evaluating the appropriate level at which action ought to challenge. Usually, structure beliefs have been gone up against by dreams of "full of feeling figuring", and HCI research has distinguished the focal position of feelings in planning client encounters. Close by the standard ease of use worries, and there is an expanding enthusiasm for inquiries concerning satisfaction, fun, and delight (Sotamaa, 2005).

Multimodal human-computer interaction - discusses the *"interaction with the virtual and physical environment through natural modes of communication"* (Jovanovic, Starcevic, Stavljanin, & Minovic, 2008).

Multimodal interaction is part of any ordinary human life, speech, movement, gesture, and shifting our gaze in an adequate flow of communication. Boosting HCI with these components of regular human conduct is the essential undertaking of multimodal UIs. Oviatt et al. gave a rational meaning to multimodal frameworks, saying that they consolidate natural personal information modalities. Computers and people set up different correspondence channels over which they exchange messages with related impacts. Multimodal connection empowers all the free and everyday connections, interfacing clients with mechanized frameworks in both information and product (Jovanovic et al., 2011).

3.5.2. Interactivity and Multimodal Learning Environments

“Interactivity means the ability to intervene in a meaningful way within the representation itself, not to read it differently. Thus, interactivity in music would mean the ability to change the sound, interactivity in painting to change colors, or make marks, interactivity in film...the ability to change the way the movie comes out.” (Andy Cameron – Theorist – Rules of Play)

“Interactivity: a cyclical process in which two actors alternately listen, think, and speak. The quality of interaction depends on the quality of each of the subtasks (listening, thinking, and speaking.” (Chris Crawford - Game designer – Rules of Play)

As mentioned in the book “*Rules of Play*,” there are various discussions over the term "interactivity", even more than “design” and “systems” (Salen & Zimmerman, 2004).

They define the model of interactivity, showing the levels of engagement that a person might have when interacting with a system.

Model of Interactivity

Four levels of engagement are considered by the authors above – when interacting with a system. Interactive activities may have all modes concurrently.

Mode 1: “*Cognitive interactivity or interpretive participation.*” – Psychological, Emotional, Intellectual; Involvement between a participant and a game.

Mode 2: “*Functional interactivity or utilitarian participation.*” – Structural Interactions, Functional Interactions; Between assets (objects inside and outside the game) and the game.

Mode 3: “*Explicit interactivity; or participation with designed choices and procedures*” – Interaction; follow the rules of the game; dynamic simulations; random events; programmed interactions in the game experience are all part of this mode.

Mode 4: “Beyond-the-object-interactivity or participation within the culture of the object” – Outside interaction related with the game experience.

Types of Interactivity in Multimodal Learning Environments defined by (Moreno & Mayer, 2007). This relates to the Multimodal Learning specifications mentioned in section 3.2.2.1., of this chapter.

Interactivity by dialoguing – “the learner can ask a question and receive an answer, or can give an answer and receive feedback.”

Interactivity by controlling – “the learner is able to determine the pace and/or order of the learning episode.”

Interactivity by manipulating – “the learner can control aspects of the presentation, such as setting parameters before a simulation runs. – Zoom in and out; move objects.”

Interactivity by searching – “the learner is able to engage in information seeking, such as by entering a query, receiving options, selecting an option, and so on, as in an Internet search.”

Interactivity by navigating – “the learner is able to determine the content of a learning episode by selecting from various available sources, such as by clicking on a menu.”

3.5.3. Tangible Interaction

In the past twenty years, Tangible Interaction, an interdisciplinary field of study has developed quite a lot, as a perceptive and robust field around the world. This field links HCI and Interaction Design but concentrates on interfaces or systems that connect the physical and digital worlds. Tangible Interaction indicates the interaction with the digital world utilizing physical objects in instinctive methods; it offers an effective way for people to engage with the digital world and also provides them with something new.

Unlike physical manipulatives, tangibles involve using physical objects that are connected to digital representations. Still, Uttal and others accentuate that for learning with manipulatives to be successful, it requires teacher assistance, children must correlate the relationship between physical and abstract relations (Bruckman et al., 2010). Another form of hands-on interface is a multi-touch interface, such as tablets and touch tables; these allow hands-on interaction with screen-based digital representations. Although

many researchers have suggested that tangibles and multi-touch interfaces might benefit children's learning, little research exists that support these claims. Most recent work still invokes high-level theories to explain possible learning effects without empirical validation. There continues to be a lack of theoretically grounded guidance for designers as to what design choices might be expected to have significant impacts (A. N. Antle, 2012).

“Tangible Interaction – systems:

- tangibility / materiality
- embeddedness in real space, and augmentation of physical spaces
- bodily / embodied interaction
- physical representation of data”

(Eva Hornecker, s.d.)

3.5.3.1. Tangible User Interfaces – TUIs

Tangible user interfaces (TUI) are interfaces where a person interacts with a digital system through the manipulation of physical objects, allowing for maneuvering of both the digital and physical world, assisting in diminishing the gap between them. Many tangible interfaces use a tabletop surface as the base for interaction, embedding the tracking mechanism on the surface. TUIs have been quite successful, and improvement has been made related to its interactive abilities between digital information and physical manipulation.

TUIs are defined by Ulmer and Ishii, as systems that utilize physical objects as representations and controls for digital information. TUIs must balance physical and digital representations. In Graphical User Interface (GUI) based systems, the screen is merely a window through which we reach into a digital world, with TUIs, the interface is blending with the environment, and the interactions are taking place in the space with the artifacts, users act within and touch the interface itself.

Terminology & Characteristics given by MIT of GUIs and TUIs:

- GUI “icons”
- TUI “phicons” (physical icons)
- GUI “menus” and “handles”

- TUI “trays” and “phandles” (physical handles)
- Unified connection of ordinary graspable objects.
- Physical Objects and Digital Interactions

Trays and handles

- GUI controls - physical form - scales and scrollbars
- TUI instruments - rotation constraint instrument

(George Fitzmaurice; Hiroshi Ishii; William Buxton, n.d.)

Tables/desks are one of the areas where research has generated a lot of good TUIs. MIT's Tangible Media Group created a platform called metaDESK, their first platform where they tested the design of TUIs that had 2D and 3D graphics as well as physical objects. Their first application for the platform was Geospace, the map of the MIT campus (Ullmer, 1997).

It's said that TUIs improve problem-solving difficulties and increase spatial cognition (Jeong, And, & Maher, n.d.; Kim & Maher, 2008). These types of interfaces are also used in various video games for children. One of these games is called Groundskeeper⁴³ created by CogCube, a game design company.

This game uses Sifteo Cubes⁴⁴, which are hand-held small cube computers; they are light and easy to manage and allow children to solve problems/puzzles inside this specific game. This creates engagement and learning through interactive play. Sifteo Cubes or Siftables⁴⁵ use not only Tangible User Interfaces as a platform but also wireless sensor networks.

There is a large percentage of researchers exploring the use of TUIs for children with learning difficulties, and this shows that such platforms encourage collaboration, playfulness, and engagement (Xie, Antle, & Motamedi, 2008). TUIs are also easier to use than traditional graphical user interfaces (GUIs) (“GUI vs. TUI: engagement for children with no prior computing experience. - Free Online Library,” n.d.) (“Proceedings of the Graphics & Multimedia ... - MAFIADOC.COM,” n.d.).

⁴³

⁴⁴

⁴⁵

REACTABLE

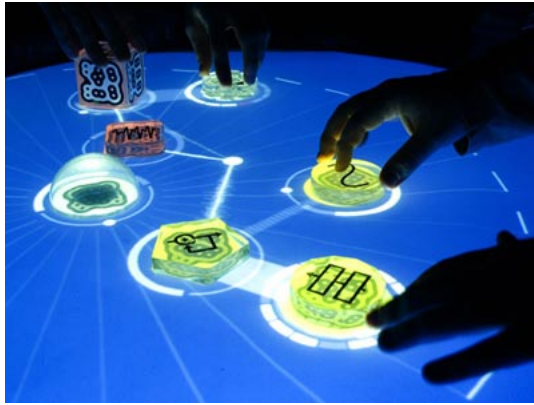


Figure 8 | reactTable

“reactTable is an Electronic Musical Instrument developed at the Interactive Systems Group at the MTG. Project led by Sergi Jordà.” (Álvaro Mendes Barbosa, 2006).

“The reactTable* is a state-of-the-art music instrument, which seeks to be collaborative (local and remote), intuitive (zero manual, zero instructions), sonically challenging and interesting, learnable and masterable, and suitable for complete novices (in installations) and for advanced electronic musicians (in concerts). The reactTable* uses no mouse, no keyboard, no cables, no wearables. The technology it involves is, in other words, transparent to the user; it also allows a flexible number of performers that can enter or leave the instrument-installation without previous announcements.” (Jordà, S. and others, 2005)” (Álvaro Mendes Barbosa, 2006).

TUIO PROTOCOL

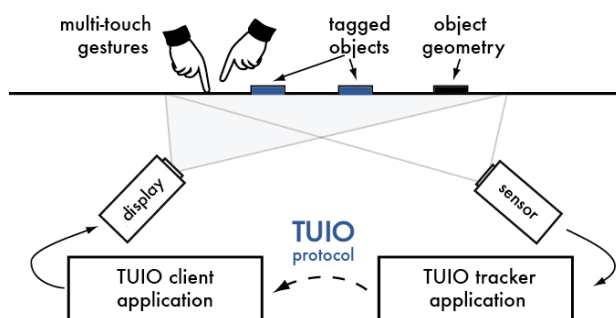


Figure 9 | TUIO Protocol

“protocol specification to the public domain, apart from its initial implementation within reactTIVision, it has been adopted by several other projects related to tangible and multi-touch interaction” ... “This protocol definition is an attempt to provide a general and

versatile communication interface between tangible tabletop controller interfaces and underlying application layers. It was designed to meet the needs of tabletop interactive multi-touch surfaces, where the user is able to manipulate a set of objects and draw gestures onto the table surface with the finger tips. The objects are tracked by a sensor system and can be identified and located in position and orientation on the table surface.” (Kaltenbrunner & Echtler, 2014), (“TUIO Protocol Specification 1.1,” n.d.).

Sensor Network

Wireless sensor networks and TUIs are original platforms that apply technology and methodology from wireless sensor networks, so as to generate new possibilities for human-computer interaction. Siftables or Sifteo Cubes are wireless compact cubic devices with a color LCD screen that has sensing, graphical display with a three-axis accelerometer, four IrDA infrared transceivers, an onboard rechargeable battery and an RF radio (Merrill, Kalanithi, & Maes, 2007). They can be physically manipulated individually or in a group when in-group they interact with each other and allow digital information and media to move through each other.

Shape Displays

Shape displays are perfect research platforms, allowing for more general-purpose shape change than many other actuated or shape-changing interfaces. inFORM is a dynamic shape display that renders 3D content physically and can also interact with the surrounding physical world. Users can interact with digital information in a tangible way, (e.g., moving objects on the table's surface), (Follmer, Leithinger, Olwal, Hogge, & Ishii, 2013)

Table Top Interaction

Tables have constantly served various functional roles, e.g., for writing, dining, or socializing. Due to the technological progress of the last decades, computers have evolved into a medium, used for interaction and sharing information. The next step in human-computer interaction would be to combine these two ways of information sharing, the table, and the PC, and create digital tabletops (Mazalek, 2005; Van Den Hoven & Eggen, 2004).

3.5.3.3. Tangible User Interfaces for Children

Tangible user interfaces are necessary because they interact with digital information through physical objects. Nevertheless, they have been examined for a while now, since TUIs still play a marginal role compared to other UI systems. This is at least partially because TUIs often involve complex hardware elements, which make prototyping and production in quantities difficult and expensive.

Considering children as the users of TUIs, historically, they learn a variety of skills by playing with physical objects, and they are born with the ability to manipulate objects with little cognitive effort tangibly. Therefore, a TUI would appear as a 'natural' form to them. Tangible technology has excellent educational potential; unlike traditional desktop computers with GUI interfaces, which have a limited assortment of physical objects and a limited range of social skills, TUIs provide direct control of physical objects and additional means of interaction.

Tangible interaction has developed as a field of study to be the subject of abundant and visionary research worldwide (A. N. Antle, Warren, Cramer, Fan, & Matkin, 2016).

Tangibles permit children to go beyond the screen and physically interact with objects that reveal information on the subjects they are learning. Various concepts following Tangible Interaction include the idea of multi-sensory interfaces that encourages new play experimentations (Intersection of the physical and digital worlds, s.d.)

The notion of multi-sensory interfaces is a common theme in Tangible Interaction design, conventional learning techniques usually engage just two senses, hearing and vision, when providing access to information. So, Tangible Interaction encourages the idea of engaging the remaining senses, vision, hearing, touch, and even smell and taste as a means for interacting with data. Tangible objects provide exploratory activities. Children can play and experiment with tangibles in a way that chalk-and-talk or screen-based information delivery methods do not support, which opens the possibility for them to learn through discovery and engage, personally with the lesson. These are just small glimpses of the opportunities for enhancing the learning experience presented by the field of Tangible Interaction. Numerous possibilities are still unexplored for designing tangibles that can engage students and provide a deeper understanding of learning material. Furthermore,

the potential for the development of new learning strategies is excellent and presents an exciting view of the future of education. (interaction, s.d.)

There are groups of educators bringing interactive digital games into classrooms since some consider technology as the most significant contributable factor in the educational progress and process of the learning environment. They believe technology has the potential of not allowing trust to thrive between the teacher and the child, but also games provide a sense of achievement. Nevertheless, some concern is brought up about the frustration and disappointment that digital games might bring to children in education.

Traditional board games use physical pieces to play with, these pieces display different functions, such as representing a player, points, money or offering a factor of chance, they can also be iconic or symbolic. Some research projects combined the benefits of digital games with board games to explored the area of pervasive gaming by carrying physical movement and social interaction back into digital games (Bakker, Vorstenbosch, Van Den Hoven, Hollemans, & Bergman, 2007).

3.5.3.4. Types of Tangible Objects

(tangible - physical play) - Systems of play and its benefits (Toy Blocks)

Benefits of Tangible Objects:

Physical - children's hands and their fingers build strength, hand-eye coordination is improved, and they learn the different shapes.

Social - children are encouraged to make friends, cooperate, interact, and use their imagination.

Intellectual - children improve their vocabulary by learning shapes, sizes, and positions. Math skills are improved by adding and subtracting.

Creative - children gain creative stimulation by making personalized designs.

Types of Tangibles used in Digital Games:

Reactable - Tangibles

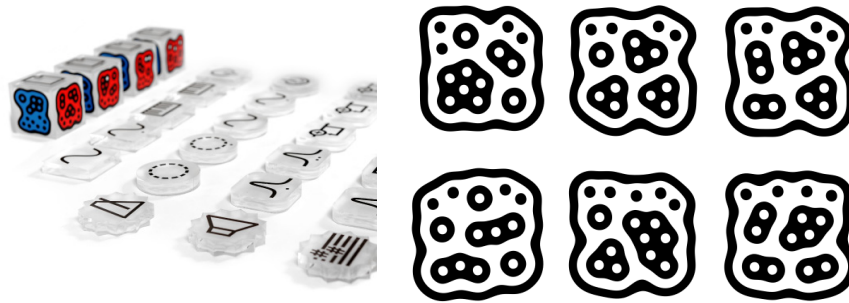


Figure 10 | E.g. Manipulatives with the Fiducials markers – (“reactIVision,” n.d.)

Magnetic Tangibles – electromagnetism

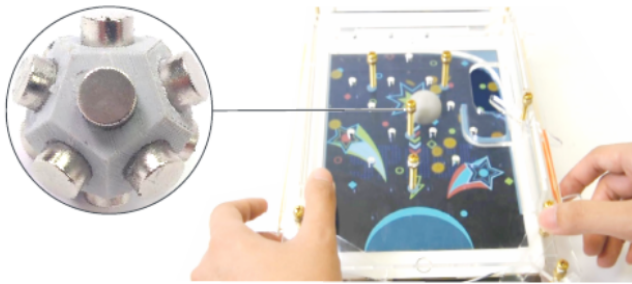


Figure 11 | E.g. Gauss Marbles (Kuo, Liang, Lin, & Chen, 2016)

“GaussMarbles is a system of spherical magnetic tangibles for interacting with portable physical constraints”

Capacitive Touch Tangibles



Figure 12 | E.g. Tiggly Tangibles

“Capacitive touch screen - control display that uses the conductive touch of a human finger or a specialized device for input”

3.5.5. Mobile & Touchscreen Technologies

Touchscreen technology consists of the direct manipulation of visual displays through gestures using a surface. This user manipulation consists of touching the screen without using any controllers. Any device that possesses touchscreen technology is called Touchscreen, which consists of mobile phones, computers, walls, floors, tablets, table, these devices are capable of “sensing” and “locating” touch. These surfaces are sensitive to the touch of human hands and fingers or even stylus.

Multi-touch consists of a surface recognizing multiple touch gestures at once on the same screen. New generations of digital technology are being crafted through interactive interfaces; they provide multi-touch surfaces and interaction directly through touch.

There is much potential in interactive technologies, since they perfectly suit the needs and wants of children, but are rarely used in children's learning environments. Interactive platforms, like tabletops and mobile devices, have been used to encourage children's play through storytelling, creativity, and collaborative interactions (Do-Lenh, Jermann, Cuendet, Zufferey, & Dillenbourg, 2010); (L.-C. Lee & Wei, 2013); (Rick, Marshall, & Yuill, 2011); (Marco J., Cerezo, E., Baldassarri, E., Mazzone E., n.d.).

Utilizing mobile games in education combines situated and active learning with fun in a potentially exceptional method (Whitton - Mobile Gaming p71, 2010).

During the last twenty years, the importance of fostering meaningful learning has been elaborated upon under the general heading of situated and active learning (Brown et al. 1989; Lave & Wenger 1991; Lombardi 2007, n.d.). Mobile and location-based technologies give us opportunities to implant learning in authentic environments and thereby enhance engagement and learning outside traditional formal educational settings.

With handhelds, it is possible to combine virtual data with real-world data to connect a virtual world to real life (Selwyn, 2010), (Eric Klopfer, 2008). Likewise, games can be played in the real world with the aid of digital devices, which make it possible to construct a fictional layer on top of the real world, creating an augmented reality. Augmented reality games that are based on locations are played in specific real-world locations, which may include historical or geographical locations.

Studies usually focus on mobile game-based learning and their engagement through them, people are completely engrossed and play for long hours with little awareness of what is going on around them (Beck & Wade 2006; Shaffer 2006). This total absorption, previously mentioned in our research, is called “flow” (Csíkszentmihályi, n.d.). This increases motivation (Watson, 2007), which is something paramount in learning and leads to motivated learners. Motivated learners are easy to describe, and they are enthusiastic, focused and engaged, they show a clear interest in what they are doing, and try hard and persist over time (Garris et al. 2002), (Huizenga, Admiraal, Akkerman, & Ten Dam, 2009a).

Schwabe and Göth (2005), in their assessment of mobile game-based learning, discovered that technology enables immersion into mixed reality and thus provides highly motivating learning experiences. In their words, the mobile game they studied moved the pupils *“into a state where they are mentally ready for learning and where they are in the right environment for learning”* However, they also acknowledge that they are unsure that the game actually enhanced pupil learning. The cognitive benefits of mobile game-based learning need to be thoroughly evaluated, notwithstanding the fact that both the cognitive and motivational effects of game-based learning have been previously studied (e.g., Mitchell & Savill-Smith 2004; Hays 2005; Egenfeldt-Nielsen 2006; Fletcher & Tobias 2006; de Freitas 2006; Gros 2007; Habgood 2007), (Peirce, 2013).

3.6. Audio-Visual Game Cues

When we talk about humans, it is essential to emphasize the way they communicate. Communication is achieved through articulating emotions through verbal vocalization signals, words, and nonverbal vocalization signals, such as pitch or rhythm.

When we talk about video games, the sense of environment is central; one way to feel it is through sound. This ambient sound transmits a sense of interaction with the game; the player interacts with the environment, and unconsciously expects specific sounds. An excellent example of this can be found in *Little Big Planet* (LBP), each of the game levels take place in various locations of the world, the ambiance music/sound is tailored to each specific location and is an asset that is felt by the player. The use of sound cues helps identify goals and focus the player's attentiveness towards particular objects. Using LBP as an example again, it uses sound cues for specific tasks/movements like a copy, select, deselect, notification, paint, fails, wins, just to name a few, they are consistent throughout the game.

(Grimshaw, 2011).

When sound cues and ambient music are used in this manner, to create awareness for the players within the game narrative, we call it "Drawing Attention" (Collins, 2007). A "soundtrack featuring a lullaby might direct attention to a cradle rather than to a fishbowl when both objects are simultaneously depicted in a scene" (Cohen 2001, 258). Music is usually used as an element to enhance the atmosphere of a game; it can signal a link between two levels or two scenes, it may relate to the opening or an ending of gameplay or animatic. Absence of sound is also an indicator, a sudden drop of silence in the middle of a game can signal something missed or left incomplete. This is seen as a hint source, and these hints are called Structural Functions (Cohen 1999, 41). Structural functions have many characteristics, and they aid the player to be more focused and immersed in the narrative, a pause/break in the music might indicate that the narrative is changing or it might just indicate a scene transition in the same level if the music theme is the same

(J. J. Lee, 2010)

In a game, sound's most significant aspect occurs when it communicates the suspension of disbelief, adding realism, or creating an illusion. The impression of being immersed in an

unrealistic 3D environment, where the overall atmosphere is enhanced by the audio, is even more evident in newer games. Sound has evolved, especially in the case of surround sound. These illusionary and spatial functions of the audio have a lot of impact in the game environment, and even small effects can further enhance this.

The most obvious example of Mood induction is when the player's character is in jeopardy, and the final boss battle plays chaotic and fast music. Sound is used to manipulate the player's

emotions and executive responses to the game "Communication of emotional meaning." Arcade games have fewer arrangements and more sound effects and percussion, as a necessity of the environment, games must be heard over the ruckus to attract players. Home consoles, on the other hand, mask the distractions of the computer fan with music (Cohen 1999, 41).

The player can interact with the sound in games in various ways, implying that audio can have a wide variety of functions. In some games, the player can get so highly immersed in the game that the sound environment is more like a calming aspect of the game than something else. It works as emotional wellbeing more than anything else. The audio and visual reactions are essential for the interaction between the player and the game. Audio and visual elements tend to complement each other, but a game designer also has to take into consideration the different categories of a user interface that assist the player walking through the game with various sounds.

Visual images in our daily lives, like signs, are usually used to show people directions, they show us what we should do and where we should go, the same thing happens in video games. So, to assist a player in video games, we can separate the visual components in two different video game interfaces. The first interface corresponds to the menus that allow the game to begin and to be played, providing specific options and modes that allow the player to customize the game. The second interface is the gameplay environment. The former has to have in consideration the rules and guidelines of usability so that the player can find what he is looking for quite easily, but the latter has to be the opposite in order to make the gameplay fun and challenging with some sort of difficulty as well (Aki Järvinen,

2002). Videos games are full of visual components, and they communicate as well as any dialogue in guiding a player through the level/game. Usually, game interfaces communicate the same visual appearance, and the player knows right then what to expect of the game itself and how to interact with it in terms of style, mood, and accessibility.

Visual elements in video game design/development have drastically changed over the last few decades, it has changed from pixel art to 3D environments/models with numerous and very accurate textures that can sometimes be felt, because of their beauty. It is a visual and emotional experience, which occurs because new-age games tend to become more complex, and the environments tend to have a plethora of graphics. Classic computer games, on the other hand, fall by the wayside and are seen as casual. One of the areas that researchers focus a lot on is the mechanics and how they affect the player's experience, but they never really investigate how the fidelity of games to real-life affects the player's experience.

Research has been done in the past few years on how the impact of graphical quality on various media mediums affects the emotional experience of a person. The most important thing is that images affect players in different ways, and the quality of those images factor in the involvement of the player in the game environment and make them perceive the game as something real.

The most prominent concern teachers have with games is that children may become antisocial; they may perceive the games as reality and come to dismiss the outside world. This issue arises when talking about high-quality visuals that engage and sometimes change the behavioral states of mind of a player.

Understanding how a player interacts with lower-fidelity graphics may be key to understanding how the player is able to learn in specific game environments and how motivation, perception, emotion, and behavior are affected.

3.6.1. Senso-motorism

When talking about video games as learning tools, it is essential to note the way players feel physiologically about games. A gamer requires all his senses, psychologically the motor activity and the sensory stimuli are very much correlated, and it is what ties the player to the game's environment activity. *"Senso-motorist accounts for the means that*

are used to get the player's so-called touch senses to interact with the information he gets through eyes and ears." For example, the capacity to guide the LBP Sackboy through mountains and fire with a game controller and make Sackboy take certain actions when pressing specific buttons on the game controller. The player interacts with the game interface in order to play the game, senso-motorist is what is needed for the player to interact with the design on-screen (Järvinen, 2002).

3.6.2. Senses & Learning

We will mention three aspects of sensing that we believe are important to comprehend the audio and visual elements in video games for learning outcomes: Emotion, Perception, and Motivation.

Emotion

There have been numerous research studies that demonstrate a central relation concerning improved mood and positive emotions when playing the favorite video game (Russoniello, O'Brien, & Parks, 2009; Ryan, Rigby, & Przybylski, 2006). As has been shown, emotions tend to blur the boundaries concerning physiological and mental situations because they are associated with behaviors, thoughts, and feelings. This can be observed in video games when the player goes from one level to another, sound and visual elements sometimes change dramatically, which alter the player's moods and emotions. There is no definitive categorization that has worked for emotions, even if there have been ways of classifying them and used them before. James-Lange focuses on the theory that emotions are related to suffering physiological alterations. Video games may be amongst the most excellent and most effective and efficient means by which people show positive feelings. Various studies have shown that playing specific video games, such as Candy Crush, Cut the Rope, Plants vs Zombies, that have few visuals, brief responsibilities with specific characters, high degree of accessibility and specific models of communication research (Ruggiero, n.d.) increase the players' attitudes, helps on fear increases relaxation, they promote well-being. They generate positive emotions in players, although they are short-term gratifications and not long-term. Game Designer Jane McGonigal suggests that some of the most influential and positive emotional experiences are generated when playing video games (McGonigal, 2011).

Perception

Perception is a visual element that is interconnected with dimensionality, but the dimension does not only control the point of perception, but it also relates to how the player is involved with the auditive and visual elements. These two elements, together, perception and dimension, define the form of the game environment. The point of perception has to do with the position of the player, where is he located in the game environment, and what is actually being seen and heard. It has to do with the viewpoint, which in various games involves at least two points of view, first-person and third-person viewpoints. It can also be compared to the leading opinion considered in concepts of narratives and narration. However, some games are interactive and do not possess any narrative nature. In these cases, players can manipulate the point of view by switching from one viewpoint (point of perception) to another. This is because the player usually sees and hears everything in the game environment, so the point of perception is a fusion of first and third person.

The option to choose between a first and third-person point of view is increasing significantly, and it even extends to specific camera angles within the game environment. So not only the visual environment changes but also the audio environment, since microphones also are involved in this process. Different places offer different audio and visual elements, so the point of perception and dimensionality alters completely. This can be often observed in shooting games, racing games, and sports games. An alternative consideration would be World of Warcraft, and the player has a point of perception that exists at the same time in the game environment, in this case, the map of the whole environment. The player can open a map on top of the game as a lightbox and examine it on top of the game environment or view it separately. Usually, the dimensions of the map are different from those of the game environment. Sometimes when the player is playing in a 3D game environment and opens a map, this may appear 2D, and the audio and visual information of the map is much less detailed than that of the game environment itself. Perception wise the map is only an abstraction of the space, so it does not show any detailed information that can only be found when the player gets near that specific location.

Again, using LBP as an example, even though we always view the character from the same point of view, when the player is walking or running (side view), we can use the camera to zoom in or zoom out and see the character's expressions and reactions.

Nevertheless, not all games permit this. Points of perception in a game environment are also to limit the possibility of a player to control the game environment fully and how much information he can discover or see.

When a player has the perception of a first viewpoint, he may have a stronger empathy with the game events and environments, but in an isometric viewpoint, used by many games that have the player as the center of the game and see the bigger picture of the game, the player may feel he is invincible. This can cause children to relate to games as if they were really, creating issues in a school environment.

Motivation

There are various characteristics in video games that aim at encouraging an active motivational style outside and inside the game setting. Professors Ph.D. Dweck and Ph.D. Molden (Granic et al., 2014) mention in their studies that it is normal for children to develop personal views about their skills and intelligence, they believe that by stimulating them they get specific motivational styles and directly affect achievement. This happens when children are admired by their personalities rather than their determination to work and be someone, they nurture an individual concept of intelligence. It is embedded in them and cannot be improved by work or study. They believe it is enough because everyone praises them.

But on the other hand, children who work hard to achieve something, develop a gradational theory of intelligence. They consider intelligence as something we can learn and refine through hard work and time, something that is flexible. We are not born with it, but we learn it over time if we work hard. Moreover, what studies have shown is that video games, in this sense, assist in the training of this gradual intelligence theory. They provide players with a real, tangible, and direct response having in relation to their efforts and hard work that players have achieved.

The good thing about video games is that it instantly rewards the player and gives its detailed feedback on achievement. Which (Vygotsky, 1992) calls as the “zone of proximal development.” This conveys a balanced feeling of accomplishment, succeeding at something, and not being discouraged (Sweetser & Wyeth, 2005). This so-called “sweet spot” is quite essential when balancing games in terms of difficulty and capability. Game

designers tend to be the masters of engagement, and they master the principles of getting players, young and old, into virtual realities and getting them to succeed in meaningful ways, even having to face challenging tasks and failures by giving them moments of positively finishing exciting tasks. Another positive aspect of games is that most of them provide adjustments dynamically quite often to their players with challenging puzzles demanding more acuity, quicker reaction times, and more ingenious solutions.

Additional to their studies, gradual versus a dependable theory of intelligence foresees if children in competitive environments will continue or give up, respectively (Dweck & Molden, n.d.). Consequently, because of these unspoken theories of intelligence and these ways of thinking amongst children, students and players have their consequences on how failure is dealt with. Failure is difficult to deal with when children believe that intelligence is a fixed ability and cannot be changed. If intelligence is seen as a gradual outcome, children see failure as an effortful engagement. It beckons the need to remain engaged, providing a positive attitude towards failure, generating better academic performance (Huizenga, Admiraal, Akkerman, & Ten Dam, 2009b).

Video games can use failure as a motivational tool, offering erratic possibilities for wide-ranging success. Persistence in the face of failure obtains cherished rewards is an essential lesson that players learn through being immersed in gaming environments (Ventura, Shute, & Zhao, 2013). Players are highly motivated in the face of failure; they remain optimistic and will repeatedly return to complete the task (McGonigal, 2011). The combination of persistence with optimism can lead to excellent educational achievements (Ventura et al., 2013).

It is normal that in some cases, certain types of games will adopt healthy and motivational styles, while others will not. What happens as well is that players have their differences in terms of characters and inclinations concerning which type of game they should play. Each player has their preference of game genres, and this may also have a different impact on how the game motivates them.

3.7. Creativity in Education

“Different strokes for different folks”

(LEGO: CREATING CREATORS)

Let's start with the basics. Creativity is not the same as “intelligence.”

(Book: “The rise of the creative class” Richard Florida)

“We believe that all children have the potential to be creative, a potential that can be nurtured over time”

(John Goodwin, CEO of the LEGO Foundation)



“Creativity, the process of having original ideas that have value.” (Robinson, 2006)

There are various games with a variety of levels that can be used in different kinds of learning environments, in K1, K2, and K3. (10) Games in schools provide a good and meaningful way of learning. [10] *“We inspire creativity when we encourage young people to express themselves through writing, poetry, acting, photography, notice and praise them for thinking outside the box and taking risks, their imaginations blossom.”* (Marilyn Price-Mitchell Ph.D.).

Everyone should have access to Formal Education, but many question its methods and see it as a way to mass-produce herds of unimaginative sheep instead of original thinkers. The criticism arises because it is seen as an obstruction in creative development.

Knowledge is constantly evolving, so the tools provided have to evolve with it. A fixed education will not prepare you for the future. Due to this, the educational institutions will require to extensively revamp their thinking to accommodate creativity as the leading factor (Lin, 2011).

Educating every individual's creative potential will be one of the essential aspects of shepherding the economies in the *Imagination and Curiosity Age*, and currently, our education system is unequipped to educate these individuals. Traditional educational methods give very little room for students to develop their creativity and out-of-the-box thinking; educators need to grab this lacking opportunity and foster creativity in schools.

Creativity is crucial in our lives, especially in educational environments; it is not only limited to technological novelties; it is multidimensional and multifaceted. Creativity is associated with the rise of new learning and working environments, lifestyles, and cultures, which in turn are conducive to creative work.

The creative attitude diffuses everything from our school culture, workplace culture, to our values and communities, it reshapes the way we see ourselves as economic and social actors and molds the core of our very identities. It reflects norms and values that both encourage creativity and strengthens its role. Furthermore, it requires a supportive environment—a broad array of social and cultural stimuli (Florida, 2012).

There have always been arguments on whether or not creativity could be increased by using the right settings in teaching and learning environments (Lin, 2011). This challenge of fostering creativity through training was given prominent consideration during the mid-twentieth century by Guilford and Torrance, two researchers who lengthen and measured individual creativity.

Developing creativity through education might have some repercussions, but following Yu Sien Lin's analysis we can encourage creativity in three ways; One - Teaching, how to provide creative and innovative practices which stimulates the development of intelligent possibility thinking, and higher-level thinking, problem-solving; Two – Environments, both external and social, should be stimulating and supportive of learners' motivation and enthusiasm, which bring us to a creative behavior; Three – Teacher's code,

having an open mind towards creative ideas or behaviors, being flexible, and respecting individual thinking (Lin, 2011).

“We inspire creativity when we encourage young people to express themselves through writing, poetry, acting, photography, art, digital media, unstructured play, etc. When we notice, and praise them for thinking outside the box and taking risks, their imaginations blossom.” (Marilyn Price-Mitchell PhD).

Knowledge is continually evolving, and the tools should evolve with it. A solid education will not prepare you for the future. Due to this, the educational institutions will require to extensively revamp their thinking to accommodate creativity as the leading factor.

Creativity needs to start as early as elementary school, placing the importance of elementary and secondary schools above university education. Kindergarten and primary education are : *“...a critical stage in children's development – it shapes them for life. As well as giving them the essential tools for learning, primary education is about children experiencing the joy of discovery, solving problems, being creative in writing, art, music, developing their self-confidence as learners and maturing socially and emotionally”* (DfES, 2003).

Educational institutions around the world, starting as early as preschool and going all the way up to higher education have acted; creativity is regarded as the core focus in their reforms. (Shaheen, 2010).

Creativity should be acknowledged by the government and as such make it the primal force for change, but in Macau S.A.R creativity and experience, in our point of view, is still being seen by many as something one is born with, instead of something that you can train and develop throughout life. Because of these views, the implementation phase is slow. Still, progress has started in the form of funds for creative industries as well as new curriculum integrations and strategies that promote creativity. In the rest of Asia, governments in PRC, Hong Kong and Singapore have been implementing creativity (creative learning) as part of their curriculums for quite some time (Lin, 2011).

Various authors debated about the lack of research on the field of creativity, as a result, there are little to no theoretical research models and no knowledge of the lengths of this multifaceted field. It is also necessary to understand the role of knowledge within the creative process, we can't create it if we don't have "*knowledge*", with knowledge being a mixture of insights, data, statistics, implied, and obvious understanding of creativity (Shabalina et al., 2016).

Creativity in schools is becoming one of the key assessment arguments, which needs to be fostered within classes so that students can apply it outside of class as well. Boosting students' creativity is making them more mindful of technology and design. Creativity is part of the thinking process of everyday life, this change is noticeable in some countries' more than others. One of the main issues of creativity in schools is that students are unable to focus on class materials and be motivated or inspired when doing it. What has been recently researched is that students that play video games tend to have more ability and be motivated to focus on class tasks. There are a few studies done on how commercial games rather than educational games (edutainment) are used in schools to improve students' abilities, to study, learn, focus, understand what courses and class materials are about and why they are important to understand culture, math, biology, history, etc.

"The education system was based on memorization, so I always thought it should be different and should be helping kids understand the reasons rather than memorizing facts..." (Nesra Yannier - NoRilla game)⁴⁶

⁴⁶ <https://www.norilla.com>

3.7.1. Creative Process

It is essential to understand the Creative Process. The creative process focuses on understanding divergent thinking and convergent thinking as the cognitive processes that trigger creativity. Divergent thinking: focuses on measuring the ability to come up with ideas or ideate, in the language of this literature. It can also be conceptualized as the ability to overcome functional fixedness. Functional fixedness is the inability to perceive objects as having functions other than those for which they are commonly used (Blanco-Herrera, 2017). Convergent thinking: focuses on the ability to evaluate ideas and to identify the optimal idea that fits specific criteria.

Digital game play provides excellent learning experiences, MEE, once again, offers players the ability to practice creative production and processes, it also offers them the learning experiences in creativity. Video/digital games can be designed to improve the development of creativity while retaining the fun value. Offering a new generation of games that will eventually blur the lines between education and entertainment. Much work is focused towards investigating the potentials, (Nacke & Lindley, 2010) definition, and limitations of immersion, motivation, perception and emotion in digital games. One of the challenges of studying them is trying to define what they mean (Blanco-Herrera, 2017).

3.7.1.1. Divergent Thinking & Convergent Thinking - Lateral Thinking

Eduard de Bono describes lateral thinking in two ways, divergent and convergent thinking.

Divergent thinking focuses on measuring the ability to come up with new ideas; it also refers to the ability to overcome functional fixedness. Functional fixedness is the inability to perceive objects as having functions other than those for which they are commonly used (Amabile, 1983), (Dr. Bono, 1970).

For the games we used for our experiments, we had into consideration free-play throughout the experiments; however, a specific time for it was given because participants need time to practice ideation. Novel ways to play the game or manipulate the pieces. New sets of goals, ideas, or how to play the game differently and still achieve their goals. This is also seen in games that give a chance to the player to create their own set of creative ideas around the game - like MEE. So, divergent thinking happens when we allow the player to create new alternatives. In our sessions, we give the participants time to generate

as many possible answers and ideas for the task at hand, an exercise in ideation (Blanco-Herrera, 2017).

Different from divergent thinking, convergent thinking is the ability to evaluate ideas and to identify the optimal idea that fits specific criteria. This happened when participants tried to access what was the best strategy to complete the game, and many of them tried to use the tangram piece, for example, directly on the screen to resolve the game. Convergent thinking is numerous times associated with crossword puzzles and creative problem-solving scenarios. There is a Remote Association Task developed by Mednick (1962) that tests convergent thinking activities. This theory perspective tests people's ability to choose one correct answer with specific groups of criteria. Remote Association Task is used to measure creativity (Akbari Chermahini, Hickendorff, & Hommel, 2012; Chermahini, & Hommel, 2012; Colzato, Wildenberg, & Hommel, 2013). Their statements focus on the creative thinker's level of a similar pyramid approach instead of a vertical akin approach. Flatter associative hierarchies increase the likelihood of forming new connections between concepts (Blanco-Herrera, 2017).

3.7.2. Theories of Creativity

It is hard to use creativity. In the multidisciplinary research related to creativity, there are various descriptions of creativity (Ackoff & Vergara, 1981). And there is little agreement on a structural framework in the field of creativity. Some argue that creativity is little more than uniqueness or innovation (Blanco-Herrera, 2017).

Margaret Boden defines creativity as the ability to manifest ideas or artifacts that are new, surprising, and valuable, and it is part of every individual's life. These are divided into two: Ideas or thoughts, i.e., concepts, theories, perceptions, and beliefs which are the internal component of creative expression; and Artifacts or man-made products, i.e., books, paintings, sculptures, vehicles, buildings which are the external component or the expression of ideas.

It is about the notion of invention, innovation, and adaption; creativity is based on daily abilities such as conceptual thinking, awareness, and memory. Anyone can be creative and can get better if working at it. During the process of being creative, we feel we are

performing at the peak of our abilities, creating works that provide us with understanding, and elevating our lives with the physical works that we share with others.

“A person needs a healthy self-respect to pursue novel ideas, and to make mistakes, despite criticism from others,” (Boden, 2004)

“Creativity involves confidence and the capacity to except and take risks. Margaret Boden mentions that creativity needs the mixture of “passion and confidence”... “Breaking generally accepted rules, or even stretching them, takes confidence. Continuing to do so, in the face of skepticism and scorn, takes even more”... “Creativity is multidimensional and experiential.” (Boden, 2004) (Florida, 2012)

3.7.2.1. Two Different Senses of Creativity

Boden describes “creative” in two distinct modes: Psychological | P-Creative and Historical | H-creative.

Psychological | P-Creative:

In any field, like, science, arts, and technology, the psychological sense is connected to ideas that are startling and novel, taking into consideration that it was the person's mind that had the idea. For example, if a person combines ideas in a way that he has never done before, or if he has an idea, he could not have had before, his idea is psychological creative. It does not matter if any other people have had the same idea before. The same thing goes for young children that can realize that, for the same time, others see the world differently from her and that everything around us when they go away, stays the same. These things for children are new and valued no matter if other knew about this before *“...they are thinking a thought that is outside all other thought that this person can conceive/is aware of at the time.”*

Historical | H-creative:

New ideas related to the history of humanity, if a person has never had that idea before, is seen by Boden as H-creative. It can be a historically-creative “combination,” or it can be a historically-creative “impossibility.” However, whichever type of creativity is involved, it is only historically-creative if no one has previously thought about it (Boden, 2004).

"Many arguments about creativity are rooted in disagreements about value" (Boden, The Creative Mind, p. 45)

3.7.3. Learning to be Creative

As mentioned above, we are often confronted by the theory that creative people are born creative, and nothing can be done to change this. However, there is a lot we can do to help people become more creative. Sir Ken Robinson says that if someone just cannot read and write, we cannot assume that they are not capable of writing. What it means is that maybe they have not learned it yet. The same goes for creativity. They do not know yet what creativity is all about.

Sir Ken Robinson mentions in his book, "Out of our minds: learning to be creative," that creativity is usually connected with "free expression," and that brings worry into people in education. Criticism is pointed out, knowing that most of these people assume children will go wild and destroy the school materials instead of really focusing on what is creativity and take this seriously.

Creativity typically involves playing with ideas, imagination, and having fun, but it is also about working hard on ideas and projects, shaping them into their best forms. Creativity is also about skill, knowledge, and control. A person can be free but at the same time, requires restraint (Robinson, 2011).

A demand for fostering creativity has become a universal discourse across different nations, reflecting the globalization of economic activity (Loveless, 2007). The function of education serves as a building block of human capital by equipping students with the knowledge and creative capacities (Lin, 2011). Policy-making and curriculum reform were carried out in order to fit this need (Shaheen, 2010).

3.7.4. Creative Play

The value of creative play is unquestionable, and great value should be given to play since it is an excellent channel for acquiring knowledge and exploring new types of ideas. For example, LEGO play is a playful type of play and learning through play, since it helps children develop new ideas and see the world they live in different ways.

Creative Play starts with inspiration and ends when a child shares an original item made using the available tools and materials. In this process, kids open up their minds to what is possible, take chances, solve problems, collaborate and become better creative thinkers and doers. These are the critical “21st- century skills” the whole world is talking about.

Creativity and 21st- century skills are easily nurtured by tapping into a child's natural creative powers; countless research supports Creative Play; it is a natural process for children, demanding limited resources, and little assistance.

Creative Play consists of Inspiration, Imagination, Building, Playing, and Sharing. Although to be effective, it must contain these elements, it does not need to follow a specific order, and they can be repeated numerous times.

“Creativity is sparked by curiosity and imagination. Creativity develops through playing and experimenting with ideas and things. Creativity is a driver for change and for adaptability.”

(Dr. Helen Charman, Director of Learning and National Programmes, Victoria and Albert Museum)

3.8. Conclusion

In this chapter, we try to give an overall background of what the approaches are and considerations when designing interactive experiences, considering, multimodal digital games for children in a specific educational setting.

Research areas, such as tangible interfaces, game-based learning, human-computer interaction, design patterns, flow in games as well as trends in the digital/educational environment, were mentioned.

Research that focuses on uncovering experiences evoked by playing digital games, such as fun that leads to positive emotions. Most gamers have felt “*Fiero*,” the Italian word for intense pride felt when one triumphs against great hardship. There is a lack of research in this area of positive emotional experiences during video gameplay.

Experiencing poised feelings was a conscious inspiration that preceded play. Nevertheless, this is not enough for games to be implemented as tools for education.

Digital games can be designed to increase the development of creativity while retaining the fun value: providing a new generation of games that will combine education and entertainment. Much work is focused on investigating the potentials, definition, and limitations of immersion, motivation, perception, and emotion in digital games.

One of the challenges of studying them is trying to define what they mean. Playing games is often considered a relaxing activity; gaming environments may nurture a tenacious, positive motivational style. This clear motivational style could reform schools and work frameworks. Players need to have designers that are sensitive and aware of their needs to be knowledgeable about the usability of concerns and be more rigorous in calculating how to create learning environments with audio and visual elements that will help the players on improving their behaviors.

It is vital to understand and study the degree in which turning to video games, to feel healthier and improve behaviors is what is necessary, and at what point using games becomes an evident strategy that may lead to less adverse outcomes.

This research takes into consideration that not much research or studies have been done in Macau S.A.R. concerning multimodal digital games and creative behaviors in the learning environment. We believe that this background overview can give us a push and help us implement more studies like this, that corroborate our experimental studies in Macau S.A.R. (chapters 4 and 5). As well as implement studies that might be done around the world, taking into consideration creative behaviors in an educational setting.

The research concerning the use of video/digital games, being used in the educational system in Macau S.A.R., is very scarce, and we believe that this invites the opportunity for more research to be done in this area of the world.

More arguments, points of view, and conclusions will be given at the end of this dissertation on the conclusions and further work chapter.

CHAPTER IV

DESIGN AND SETUP OF THE EXPERIMENTS

||| METHODOLOGY

CHAPTER IV

4. Design and Setup of the Experiments ||| Methodology

Our studies were conducted in the Macau S.A.R., which boasts a richness in diversified ethnicities, such as the Chinese, Portuguese, Macanese, Filipino, Indian, Singaporeans, and many others, which makes cross-culture communication and understanding crucial to learning and working together.

Exploration of how multimodal audio and visual games *can be* used in learning environments for children, specifically by fostering creative behaviors through User-Centered design approaches and creative play. -- This was our basis to start this whole experimental study.

4.1. Empirical Study

The studies conducted during this research were explicitly experimental and comparative (e.g., comparing educational games with entertainment games, or juxtaposing the ‘anatomy’ of games with pedagogical theories). However, our research interests rapidly transformed to include the complex real-life systems that educational games are developed to be a part of, the research method was taxed to transform with it. These changes, which were primarily brought about by experiences during the field-work, naturally also extended into the theoretical grounding upon which the continued research rested, and through which previous efforts evaluated. Methodological changes were not without structure or forethought, but rather a product of an overarching research strategy that emphasized the iterative refinement of methods with grounded explorative studies as its genesis.

4.2. Approach

We started with the experimental studies in a public school in Macau S.A.R., followed by two other studies in a private school and a semi-private school where we conducted a comparison between them. All three schools comprised of three different languages for communication, Chinese, Portuguese, and subsequently English, to a specific target audience.

We exposed children to two different types of gaming platforms and assess children's reactions and behaviors towards different off-the-shelf commercial digital games using specific game learning platforms (OSMO™ and Tiggly).

This comparative study allowed us to understand how children behave towards these types of digital games in the learning environment as well as understand how they tackle actions and reactions towards creativity.

One of the main specifications studied was how children could comprise to be more critical and creative in the way they think, as well as how they tend to be more creative after they have played these games in the learning environment — demonstrating how they can be more open to different approaches and different types of learning that involve digital games, as tools, that assist on successful creative behaviors.

4.3. Sampling of Participants

In order to examine the significance of “multimodal systems” (Berti & Paternò, 2005), called by some, hybrid games, for creative behaviors in a learning environment, fifty-three boys and girls aged between three and six, were observed in a similar environment. No exclusion of students with ADHD, Speech problems, Learning difficulties, or dyslexia.

53 Children | Multicultural | Multilingual | Male & Female

3 Schools | 3 Age Clusters | 3 School Levels - K1 - K2 - K3



In the first school, the psychologist pre-selected eighteen participants from different cultural backgrounds including, class, gender, and nationality. In the second and third schools, the teachers, and teachers' assistants, chose the participants.

We had no control over this matter. The psychologist and the teachers had a set of requirements for what was needed. The study included six participants from each of the kindergarten levels, Kindergarten level one, level two, and level three.

Participants at each school and kindergarten levels were chosen after the parents had given their consent to participate in the study, as well as the school's approval.

For the school's consent, we had to have the Kindergarten Director and explain to them the games as well as how long everything was going to take.

A letter of consent (Appendix A) was created for the parents in three different languages, which was edited by the schools where needed, detailing what would transpire in the school and why the children were a necessary component.

Qualitative Analysis – The selection was not random; the parents' consent was a factor.

Quantitative Analysis – The psychologist and teachers pre-selected all the participants.

Table 3: School Students in the academic years, 2016/2017 and 2017/2018 in Macau by age and gender.

Age	2016 / 2017		2017 / 2018	
	Male	Female	Male	Female
3	3212	3016	2948	2673
4	3090	2788	3496	3136
5	3550	3170	2792	2627
6	2818	2664	2639	2441

(DSEJ, s.d.)

4.3.1. Clusters - (Three Kids per Session)

We choose to run with a small group of students, for we believed it would provide us with more valuable input into the game design without becoming overwhelming or unmanageable with the amount of data we would gather (Whitton, 2010).

One of the main things about these schools and Kindergarten levels was that we could not disrupt much of their daily activities; this had to be part of a regular daily activity setting. Students should not feel overwhelmed or afraid of this kind of experiment. This was part of the agreement made between the schools/classes, and disruptions were to be kept to a minimum.

Although the schools were rigorous with their specifications, two of the schools were more open to these kinds of studies. However, all of them participated and cooperated. All the experimental studies in the schools had to be done following each schools'

guidelines and during their daily morning activities. The students participating in these studies would leave their classes during the amount of time we needed and then went back in. Most of the time, these activities were done in the morning, since the schools believed that students would be more aware of what they would be doing.

4.3.2. Experimental Studies Groups

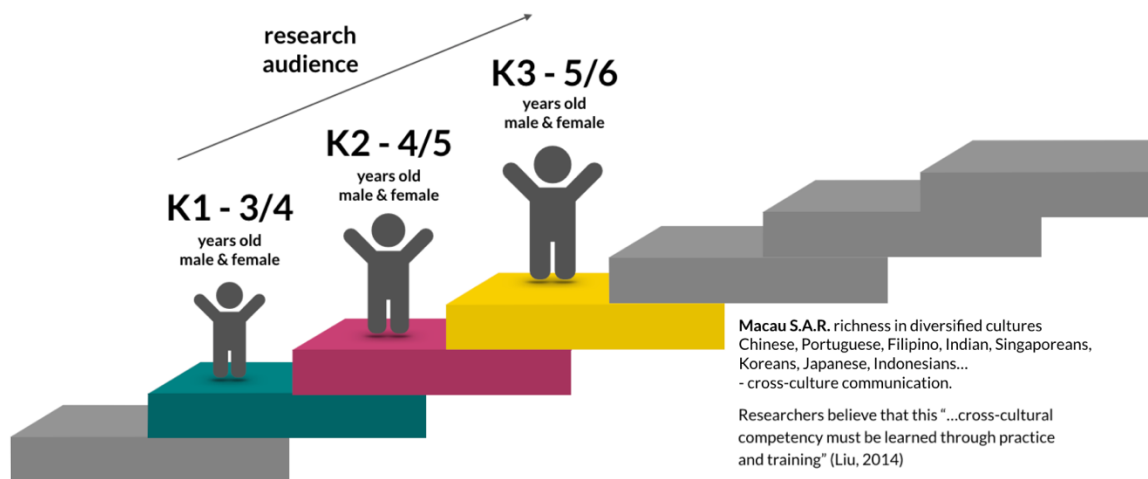


Figure 13 | Participants age and kindergarten level diagram.

School 1 | Average classes of 15 to 20 students.

Table 4 | Sample of students at school 1.

Level	K1		K2		K3	
Gender	M	F	M	F	M	F
Number of Students	3	3	3	3	3	3
Remarks			1 participant with ADHD. 1 participant was absent and another filled in during the second part of the study, male.			

Table 5 | Students registered at school 1 in 2017/2018, per Kindergarten level.
– During our study.

Year	2016/2017	2017/2018
	M/F	M/F
K1	40	41
K2	29	41
K3	17	28

(DSEJ, s.d.)**School 2 | Average classes of 20 to 25 students.**

Table 6 | Sample of students at school 2.

Level	K1		K2		K3	
Gender	M	F	M	F	M	F
Number of Students	3	3	3	3	3	3
Remarks			1 female participant was absent and another filled in during the second part of the study, male.			

Table 7 | Students registered at school 1 in 2017/2018, per Kindergarten level.
– During our study.

Year	2017/2018
	M/F
K1	100
K2	100
K3	99

(DSEJ, s.d.)**School 3 | Average classes of 25 to 30 students.**

Table 8 | Sample of students at school 3.

Level	K1		K2		K3	
Gender	M	F	M	F	M	F
Number of Students	3	3	3	3	3	3
Remarks	A male participant was absent for the first part of the study.					

Table 9 | Students registered at school 3 in 2017/2018, per Kindergarten level.
– During our study.

Year	2017/2018
	M/F
K1	218
K2	194
K3	201

(DSEJ, s.d.)

4.4. Experimental Environments

4.4.1. Schools Selection



Leading research studies in schools has its perks, it is challenging, but it fosters excellent results, and it brings lots of opportunities for future research. Schools are an excellent source of participants, so that is why we choose schools as our primary location. Our studies, like many studies around the world (Alibali & Nathan, 2010), did not involve observing or experimenting in classrooms, but instead, involved pulling children out of the class for individualized testing in a separate room at the school. This made the study more accurate as well as provided more privacy from all the students that would not be involved in the study. The sample of participants is also more accurate and inside the cultural environment of the territory

Nevertheless, the quality, variety, and characteristics of the sample of participants also depended on the chosen school as the research location. Permission was one of the main problems of getting access to these schools, as a research site. In some cases, school regulations and curriculums and government regulations would prohibit this kind of experimental study, citing that yearly progress depends on the student's well-being, i.e., scores, performance, and no distractions. Also, having students removed from their regular school activities during the day would be quite challenging to get an approval for, this is based on experience and lots of explanations to the directors, teachers, and psychologists of the school (Alibali & Nathan, 2010).

However, the schools chosen for our research were quite open to these studies, and we believe that because this was a different and more open type of structure in a research study. The type of research also helped since it involved video games and education, and the schools were quite open to it.

Macau S.A.R. is not a place where these kinds of studies are conducted every day. So, the excitement of being involved in something innovative was also one of the main reasons the schools approved our study.

An essential aspect when we were in the meetings with the schools was that the research student was the one doing the experiments and not an assistant, company or a helper, so this personal asset was a plus. We believe that providing personal, responsibility driven, and customizable experimental studies are some of the main characteristics when getting a school to approve research studies.

4.4.2. Schools Backgrounds

In Macau S.A.R., a few schools have a multicultural environment, and classes are full of students of different backgrounds. It was one of our objectives to have schools that would have students that would speak different languages as well as have different ways of thinking based on their cultures and customs. It was a challenge to find games that would be suitable for all cultures as well as language transversal so that it would be easier for acceptance by the directors and teachers.

For the first school, we choose a school that taught the official languages of Macau S.A.R., i.e., Portuguese and Chinese, as well as English as an additional language, Public School, public curriculum. This school, apart from having a multicultural background, it is also a traditional school. For secondary school, we choose a private school that taught English and Chinese and was also multicultural. For the third school, we choose a school that taught in Chinese and English, and this school was a government-funded semi-private school.

4.4.3. Setup the Experimental Rooms

In all three schools, the studies were conducted in an empty classroom, usually used for parent/student meetings. Chairs and tables were provided. We had to rely on the available materials (tables, chairs, room); it was not easy. All rooms used in the three schools were different. Some were small, some were not appropriate, and others quite distracting. Despite all this, we worked around the issues to provide stability and coherence between each school.



Figure 14 | School 1
Photo - Example setup
in experimental room -
Serpentine shaped table.

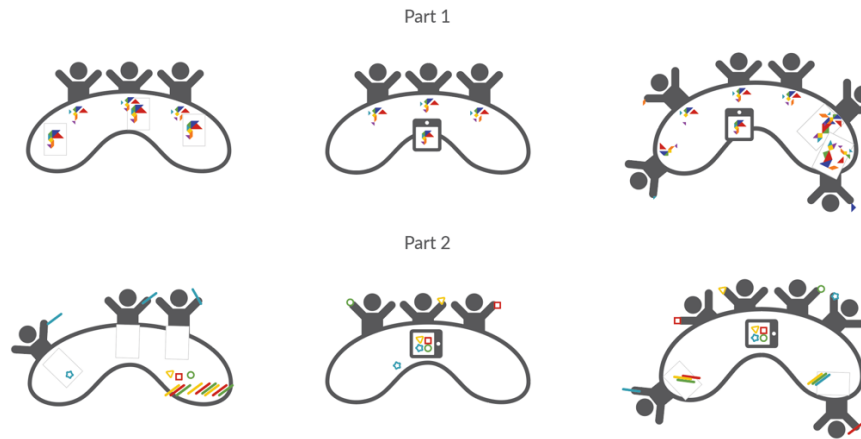


Figure 15 | School 1 - setup of for Part 1 and Part 2 of the study.



Figure 16 | School 2
Photo - Example setup
in the experimental
room – Two rectangular
tables.

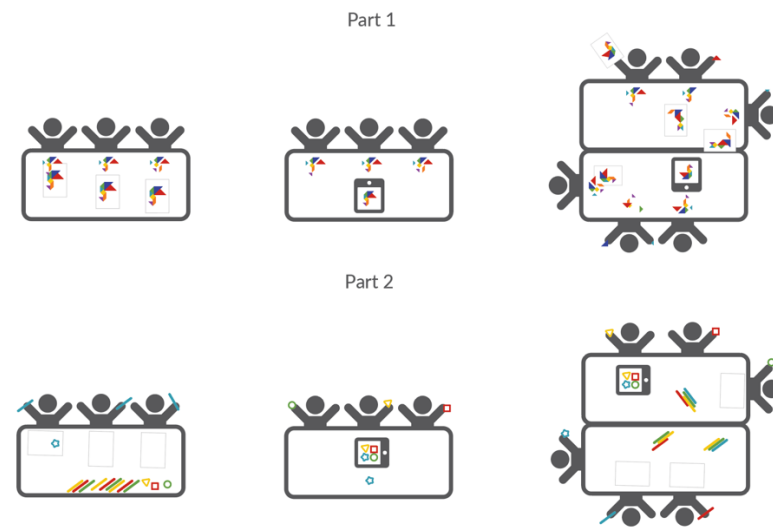


Figure 17 | School 2 - setup of for Part 1 and Part 2 of the study.



Figure 18 | School 3
Photo - Example setup
in the experimental
room – One round table.

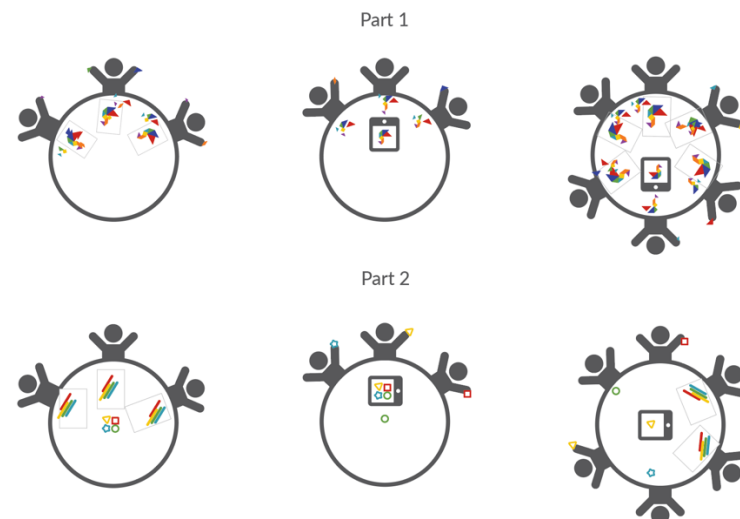


Figure 19 | School 3 - setup of for Part 1 and Part 2 of the study.

4.5. Choosing the Resources

4.5.1. Games and Materials for Part 1 & Part 2



Figure 20 | 5 puzzles used - Figures that were printed on A4 paper for guidance.



Figure 21 | Tangram Laser Cut Pieces.



Figure 22 | Crayons used in the experiments.

4.5.2. Game Platforms (used in learning environments)

In our studies, we have utilized multimodal games, such as OSMO and Tiggly, both of these commercial/educational games combine tangible and intangible interfaces and they take advantage of tangible physical objects and digital mobile devices.

OSMO is a game platform used for learning that is transforming the way children learn and play with digital mobile devices and tangible objects and has earned much recognition. Children get acquainted with the spatial relation between the physical objects and the digital device. Many schools have adopted the game to teach 21st-century, such as creativity (Scott, 2015).

Tiggly is another game platform for learning that provides engaging games that are fun and utilize hands-on “manipulatives” and digital software that can engage children in a classroom. The Tiggly game that we used in our experimental studies was Tiggly Shapes.

These systems are also being used in schools as educational tools, generating creativity (Scott, 2015)(Lento, n.d.)(Robinson & Aronica, n.d.) Both systems provide school edition versions.⁴⁷ The success of these multimodal commercial games in the classroom varies, but there are some crucial ways to implement them successfully (Groff et al., 2010). Firstly, make clear what the learning objectives are; secondly, not all games need to be used as a whole, only retain what is necessary, and thirdly, familiarization with the game is very important for teachers and students (R Sandford, Ulicsak, Facer, & Rudd, 2006).

⁴⁷ As of 2018, we believe that Tiggly is not operational, however we did not find anything related to this online since their facebook page is still on.

4.5.2.1. Tangram Game // Osmo Platform



Figure 23 | Tangram - Osmo Learning Platform

Game Platform Assets

- iPad tablet – first generation
- (although when we started this research this platform was only compatible with iPad tablet, now it is also compatible with Fire tablet)
- Reflector clip
- Stand for the iPad
- Tangram Tangible puzzle pieces (OSMO)
- Tangram Tangible puzzle pieces – created by us – six sets of seven pieces.



Figure 24 | Reflector



Figure 25 | 7 Puzzle Pieces



Figure 26 | Osmo Stand

Installation

We had to download the game/app over the Apple store and install it; after that, we had to create an account for the specific games to work and gather our data.

Setup

To prepare the session with the OSMO system, we had to set up the platform by using an iPad and get it in the stand and clip the reflector on the top of the iPad where the camera is located. After that, we just opened a specific app and started the game.

Instructions

Short game instructions are provided on the first version of the game. Instructions have been improved a bit in the updated version.

Intention

We choose to use the Tangram, a reimagined, and redesigned ancient Chinese game. OSMO created a new gaming experience, where children discover and familiarize themselves with geometric shapes, animals, people, color, etc. The main focus is fun, interactive play, object recognition, spatial awareness, the use of physical wood pieces that interact with the images on the screen generate problem-solving skills in vision and spatial environment. Another reason we chose this game was that this is a familiar game within the schools and homes in Macau S.A.R., classrooms usually have this game. Although the schools we went to were different in terms of curriculums and ways of teaching, all three had this puzzle game.

Physical Objects – Manipulatives

Color of each piece: blue, red, green, cyan, purple, yellow, and orange.

Form of each piece: triangle x5, square x1, parallelogram x1



Figure 27 | Tangram Manipulatives

Mechanics

To understand this, we made use of the Tangram game in our experimental studies. We first, laser-cut plywood pieces, six sets of seven shapes, and painted them with the respective Tangram colors and sizes resembling the OSMO wooden physical pieces.

- The seven pieces can all individually interact with the iPad, and give real-time feedback in the specific puzzles that show on the screen.
- There are various puzzles available, starting with two shapes and ending with six shapes.
- Four different skill levels – Easy, Medium, Hard, Harder (challenge level). Each level has a specific color: easy = yellow, medium = orange, hard = red, and challenge = blue.
- More than four hundred puzzle games.
- Different Modes – Junior, Treasure, Classic.
- First version of the Tangram game; without the updates, kids would be able to play puzzles and earn rewards, stickers were the reward given to the player once the puzzle is completed.
- Arrange the physical shapes on the table to match the on-screen shapes.
- Players can play with a partner or alone.
- Identification of shapes and colors.
- There is a story behind the Tangram game. The storyline is defined throughout the game. Journey the Tangram world by solving animal puzzles that will eventually take the player to the castle, which contains three puzzles of either humans or objects. Unlocking.
- Players can replay the puzzles they already solve.
- Players can play other puzzles that are harder within the trajectory to the castle if they cannot finish the easy level puzzle.
- There are types of puzzles within the game that are more advanced that do not have the color recognition function; players will have to recognize the shape only and not the shape with the color.
- Hints are also available throughout the game...

Gameplay – Short Description

At first, the player will always have to identify the main two more substantial pieces of the Tangram puzzle pieces, the red and the blue, and move it in front of the tablet, in order for the reflector to recognize it. The player will need to display the physical pieces in front of the screen in order for them to be identified by the system. Once this has been done, the player can select the first puzzle and play, while playing he has to display the pieces in the correct positions and colors. Once the player has finished the puzzle, he will earn a reward and go through to the next puzzle, raising the difficulty level.

Interface Design

Six Screenshots of the Interface Design



Figure 28 | Opening Screen

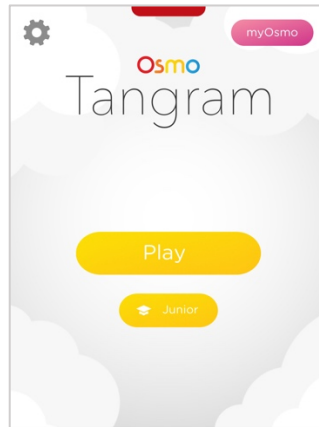


Figure 29 | Main Screen

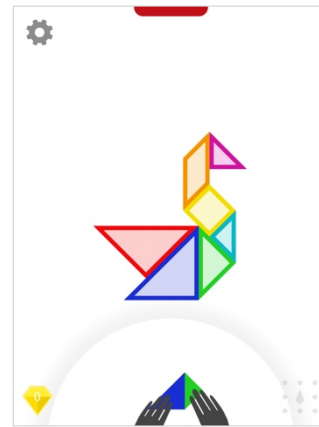


Figure 30 | Gameplay Screen

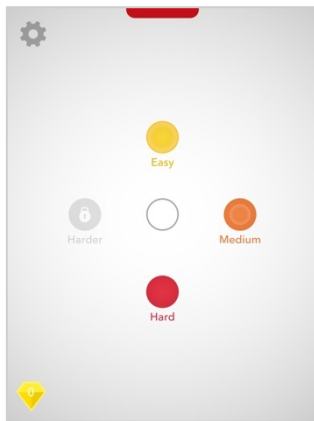


Figure 31 | Difficulty Level Selection



Figure 32 | Level Selection - puzzles

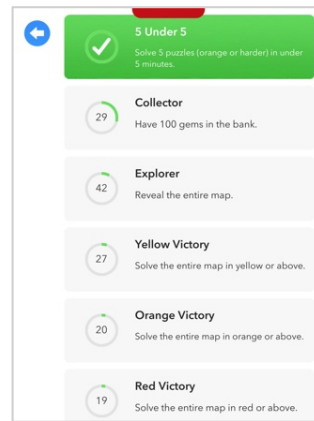


Figure 33 | Figure: Achievements Screens

4.5.2.2. Shapes Game | Tiggly Platform



Figure 34 | Shapes – Tiggly Learning Platform

Game Platform Assets

- iPad tablet – first generation
- (although when we started this research this platform was only compatible with iPad tablet, now it is also compatible with Fire tablet)
- Four Tangible Objects

Installation

We had to download the game/app over the Apple store and install it, after that, we had to create an account for the specific games to work and gather our data.

Setup

To prepare the sessions with the Tiggly platform, we just made sure the apps were installed. After that, we just opened the specific app and started the game.

Instructions

Short game instructions are provided on the first version of the game.

Intention

We chose to use the Shapes Game due to its geometric shapes that children this age are familiar with. The main focus is fun, interactive play, objects recognition, spatial awareness, motor coordination. Although the schools we went to were different in terms

of curriculums and ways of teaching, all three had these geometric shapes as part of their classrooms.

Tangible Objects

Color of each piece: yellow, green, red, blue.

The shape of each piece: triangle, circle, square, star pentagon.

Colorful Soft Shapes with Capacitive Touch | Passive Tangible Objects - everyday physical object. No fixed functionality. ("phicons" by Ishii et al.)



Figure 35 | Triangle Tangible



Figure 36 | Circle Tangible



Figure 37 | Square Tangible



Figure 38 | Star Tangible

Mechanics

To understand this, we made use of the Tiggly platform that used the basic geometric shapes for kids, “Tiggly Shapes.” In this part of our experiment, we used only the four shapes provided by the system; we did not replicate the pieces.

- The four pieces can individually interact with the iPad and provide real-time feedback throughout the gameplay.
- There were three games/levels available in the Tiggly Shapes platform.
- Three different games were provided by the system.
- Shapes Bundle Games:
 - Safari, Stamp, Draw.
- Arrange the physical shapes on the table to play different games.
- Players can play with a partner/s or alone.
- Identification of shapes and colors.
- Storyline is related to animals.
- Players can replay the games.

- Hints are also available throughout the game...
- Two different types of gameplay were provided: one where the player uses their fingers and the other using the tangible objects with the iPad.
- Take a photo and/or record a video of the game.
- Sharing functionality.

Gameplay

Safari – At first, the player will have to identify the main four tangibles in order to activate the Tangibles mode. Once done, the player is sent to a screen where he selects the game level. There are three levels. Afterward, the player sees the shape displayed on the screen and proceeds to select the physical shape with his hand and places it on the top of the screen. If done correctly, the screen will show an animal-based on the shape, emitting a sound related to that animal.

Stamp – In this game, the player first chooses a theme, based on the four seasons. Once selected, the player can stamp different shapes using the tangibles with his hand, creating various characters and construct a storyline.

Draw – This game differs slightly, as the player is required to play with both the tangibles and his/her fingers, in order to access the various features pre-designed in the game. This is fascinating because it exploits both modes of interaction and allows the player to create his/her own gameplay, using already a pre-set of features.

Interface Design

Six Screenshots of the Interface Design – example of the game Safari.

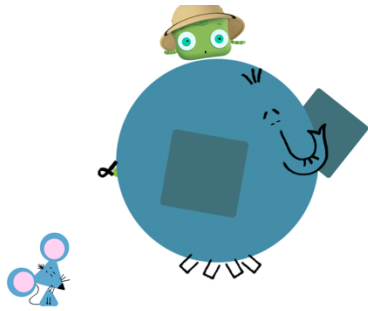


Figure 39 | Opening Screen



Figure 40 | Main Screen



Figure 41 | Gameplay Mode Selection

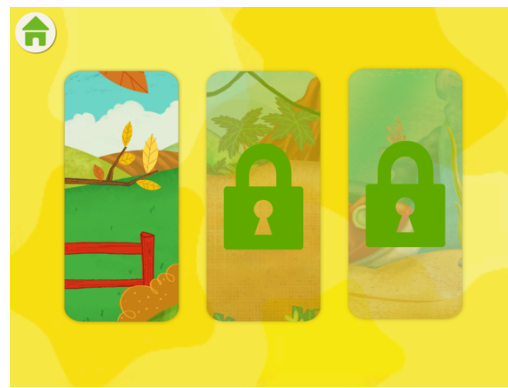


Figure 42 | Level Selection - Safari

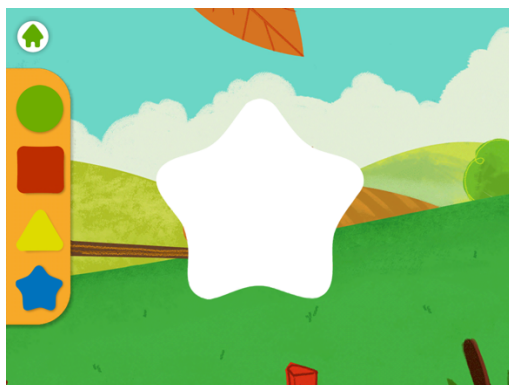


Figure 43 | Gameplay Screen - Safari



Figure 44 | Solution - answer

All the following games, physical objects, and digital platforms are applied to the Macau S.A.R. learning environment where parents, family or schools have the means to buy or have access to them.

Tangram Puzzle Game – Ancient Chinese game that is known o mostly every child in Macau S.A.R. – connection to cultural background.

Geometrical Shapes – Basic Shapes that are part of a child's development play and learning environment in the Macau S.A.R schools and centers.

Crayons – Basic learning tools for children to draw and play that are part of a child's development stages play, and learning the environment in the Macau S.A.R schools and centers.

Paper – Basic learning tools for children to draw and play that are part of a child's development stages play, and learning the environment in the Macau S.A.R schools and centers.

Digital Games with Tangible Objects and Manipulatives – Access to digital platforms – any child that has access to technology.

4.6. How was the experiment setup and why?

All the studies were recorded from the moment the participants began playing the game to the moment they stopped and left the room.

For the first part of our pilot experimental study, we collected the data by using two video cameras and a sound recorder in the room, for the subsequent studies we removed the sound recorder and added an extra camera to give us an extra point of view. This was done so that both individual and collective data could be obtained simultaneously and more accurately.

We did not use the original pieces of the Tangram game provided by the game. Instead, all printed and physical materials, including the wood pieces, were created by us and were readable by the game system. (we tested it by mixing some of the pieces as well as using all the original pieces or all the wood pieces created by us, before the experimental study sessions). We created this because our study would need to use more than one set of pieces at a time, taking into consideration the number of participants we had in each session.

For the Shapes game, we only used the original pieces since our objective was to add another element: crayons. We wanted to observe how the pieces were used for collaboration and sharing purposes.

The research student was the person collecting the data, and all the participants had preliminary instructions and explanations on how to play the game and what the objective was.

4.6.1. Pilot Experimental Study Explanations

We divided the research study into two parts, and two digital/tangible game platforms were used in each respective part. Each part contained three sessions, the first two sessions consisted of two different groups of three participants, and the last session was a free-play environment that combined the first two groups, repeating the study done to the individual groups. This method was applied equally to the K1, K2, and K3 levels.

PART 1 – Descriptions

In the first session, the study was done with two groups of three participants with the printed version, in the second session, the study was done with the same two groups of three participants with the digital version and the physical pieces. In the third session, both groups were assessed together in a free play environment, which included the combination of the physical and digital sessions.

In the first session, when we organized the study, the first group of three participants sat down in a random manner at the table, and three sets of Tangram pieces were given to the participants with the corresponding Tangram image based on the first level of the OSMO Learning Platform. Each of them had their own set of plywood pieces and their own A4 paper where the Tangram image was printed on. The printed image pieces were the same size as the respective Tangram physical pieces.

In the second session, the first group of three participants sat down again, and three sets of Tangram pieces were given to the participants as well as the OSMO Learning Platform. Each of them had their own set of plywood pieces, and together they tried to play the game.

In the third session of the study, all six participants from their respective kindergarten levels got together and sat down in a random manner; they played both the paper version

as well as the digital version. Experiment study structure: multimodal digital games - (tangible and digital platforms).

Structure of Study - Tangram

Game: tangram

Game platform: Osmo

Dates: March 2018 to April 2018

Location: confidential (document signed)

Levels: k1 - k2 - k3 / 3-4; 4-5; 5-6 years' old

Everyday common setup to all days and sessions

All the setup was done by the research student and the student helper (Cantonese translator).

Setup – Three cameras and one surround sound recorder.

8:00 am – 30 min

Starting time

8:30 am – participants start to come in the room and start to sit.

Explanations and instructions

- five minutes

- the room should only consist of those responsible: a teacher or psychologist, the research student and the students.

K1 – day 1

Total of five participants

K1 – group 1 // three participants

Session 1 - 15 minutes – three to two participants at the same time – with paper and physical objects

Session 2 - 15 minutes – the same three participants at the same time – with digital interface and physical objects

K1 – group 2 // three participants

Session 1 - 15 minutes – three kids at the same time – with paper and physical objects

Session 2 - 15 minutes – the same three participants at the same time – with digital interface and physical objects

mixed session (free play)

K1 – group 1 & 2 // six participants

After the two sessions – 15 to 30 minutes free-play

k2 – day 2

Total six participants

K2 – group 1 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects
- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K2 – group 2 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects
- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K2 – group 1 & 2 // six participants

After the 2 sessions – 15 to 30 minutes free-play

K3 – day 3 // total six participants

K3 – group 1 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects
- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K3 – group 2 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects
- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K3 – group 1 & 2 // six participants

After the two sessions – 15 to 30 minutes free-play

Summary Diagrams – Part 1



Figure 45 | Session 1 - Paper

A4 paper + Physical pieces
Tangram Puzzle Game



Figure 46 | Session 2 - Digital

OSMO Learning Platform + Physical
pieces Tangram Puzzle Game



+



Figure 47 | Session 3 – Free Play

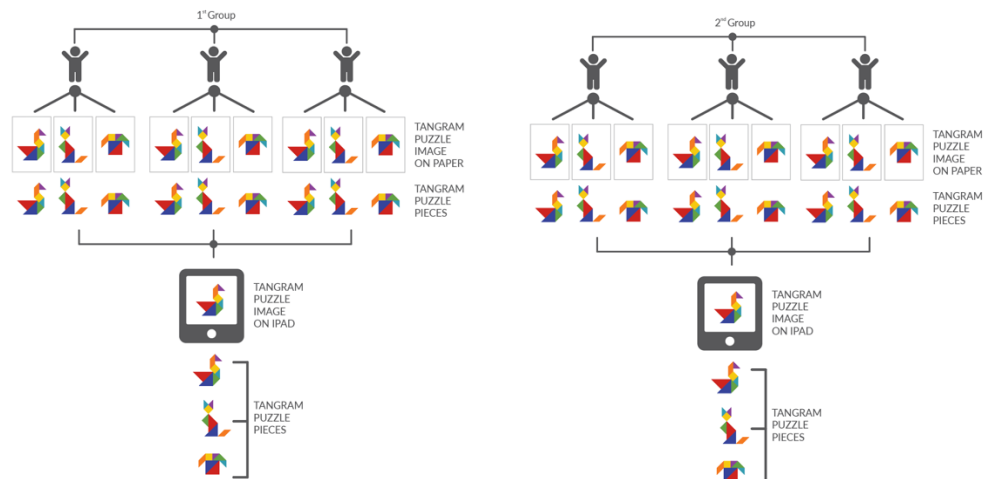


Figure 48 | Framework for the pilot experimental study approach, session 1 and session 2. This is an example of the study for the first group. This setup was for all K1, K2 and K3 experimental studies for session 1 and session 2 of part one of the experiment studies.

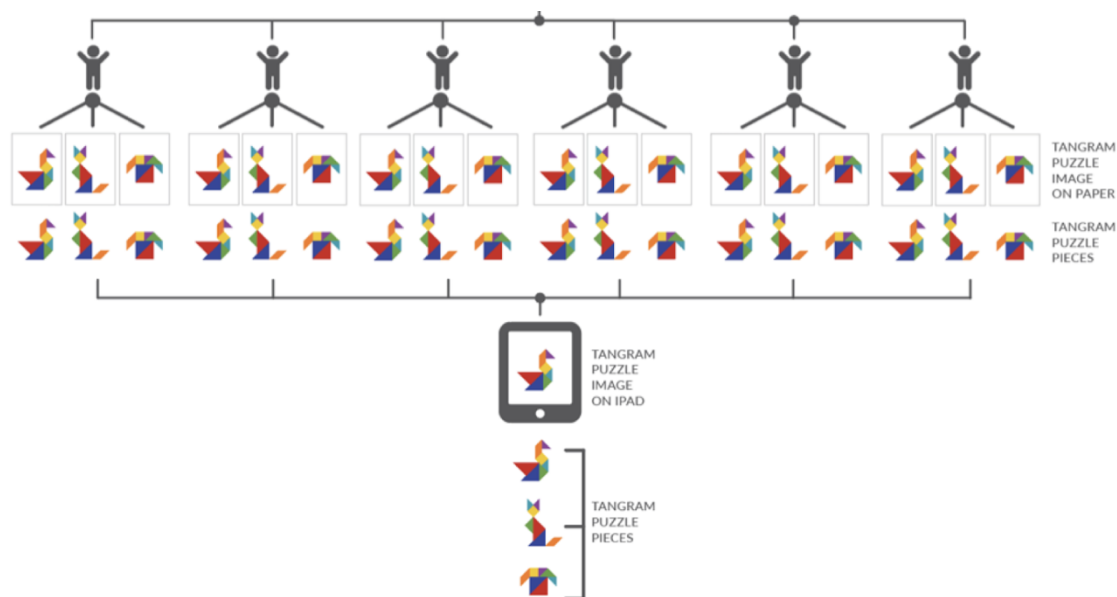


Figure 49 | Free Play - Framework of pilot experimental study approach, two groups, part one.

Table 10 | Structural Explanations – Part 1

FIRST DAY K1 / 3 – 4 years' old	SECOND DAY K2 / 4 – 5 years' old	THIRD DAY K3 / 5 – 6 years' old
- 6 participants total - 15 minutes each session	- 6 participants total - 15 minutes each session	- 6 participants total - 15 minutes each session
First Group // 3 participants 1 Boy - 2 Girls (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (OSMO Learning Platform) + physical pieces	First Group // 3 participants 1 Boy - 2 Girls (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (OSMO Learning Platform) + physical pieces	First Group // 3 participants 2 Boys - 1 Girl (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (OSMO Learning Platform) + physical pieces
Second Group // 3 participants 2 Boys - 1 Girl (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (OSMO Learning Platform) + physical pieces	Second Group // 3 participants 2 Boys - 1 Girl (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (OSMO Learning Platform) + physical pieces	Second Group // 3 participants 1 Boy - 2 Girls (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (OSMO Learning Platform) + physical pieces
3 rd Session Free Play // 6 participants 3 Boys - 3 Girls (preferable) - print (A4 paper guideline) + physical pieces - digital (OSMO Learning Platform) + physical pieces	3 rd Session Free Play // 6 participants 3 Boys - 3 Girls (preferable) - print (A4 paper guideline) + physical pieces - digital (OSMO Learning Platform) + physical pieces	3 rd Session Free Play // 6 participants 3 Boys - 3 Girls (preferable) - print (A4 paper guideline) + physical pieces - digital (OSMO Learning Platform) + physical pieces

PART 2 – Descriptions

In the first session, the study was done with two groups of three participants. In the print/physical session, the participants used a blank paper, crayons and the part of the physical shape of the digital game platform, in the second session, the study was done with the same two groups of three participants with the digital version and the physical shapes. In the third session, both groups were assessed together in a free play environment, which included the combination of the physical and digital sessions.

In the first session, when we organized the study, the first group of three participants sat down in a random manner at the table, and three sets of Tangram pieces were given to the participants with the respective shape based on the first level of the Tiggly Learning Platform.

Each of them had their own set of plywood pieces and their own A4 blank paper where they could design anything they wanted but using the shape they had on their hand.

In the second session, the first group of three participants sat down again, and three sets of Tangram pieces were given to the participants as well as the Tiggly Learning Platform. Each of them played with one shape, and they played the game collaboratively.

In the third session of the study, all six participants from their respective kindergarten levels got together, and sat down in a random manner. They played both the paper version as well as the digital version. Experiment study structure: multimodal digital games - (tangible and digital platforms).

Structure of Study

Game: Shapes

Game platform: Tiggly

Dates: March 2018 to April 2018

Location: confidential (document signed)

Levels: k1 to k3 / three to six years' old

Setup – three cameras and one surround sound recorder – research student will do this.

8:00 am

– 30 min

Starting time

8:30 am

– participants start to come in the room and start to sit.

Explanations and instructions

- five minutes

- the room should only consist of those responsible: a teacher or psychologist, the research student and the students.

Day 1 – k1

Total six participants

K1 – group 1 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects

- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K1 – group 2 // three participants

- 15 minutes – three kids at the same time – with paper and physical objects

- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K1 – group 1 & 2 // six participants

After the two sessions – 15 to 30 minutes free-play

Day 2 – k2

Total six participants

K2 – group 1 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects

- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K2 – group 2 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects

- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K2 – group 1 & 2 // six participants

After the two sessions – 15 to 30 minutes free-play

Day 3 – k3

Total six participants

K3 – group 1 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects

- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K3 – group 2 // three participants

- 15 minutes – three participants at the same time – with paper and physical objects

- 15 minutes – the same three participants at the same time – with digital interface and physical objects

K3 – group 1 & 2 // six participants

After the 2 sessions – 15 to 30 minutes free-play

Summary Diagrams – Part 2



Figure 50 | Session 1 - Paper

**A4 paper + Physical pieces
+ Crayons**



Figure 51 | Session 2 - Digital

Physical pieces + Tablet



+



Figure 52 | Session 3 – Free Play

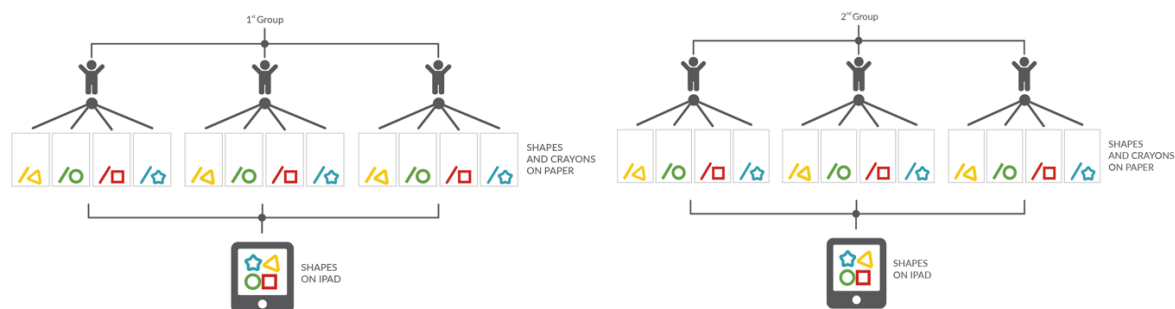


Figure 53 | Framework for the pilot experimental study approach, session 1 and session 2. This is an example of the study for the first group. This setup was for all K1, K2 and K3 experimental studies for session 1 and session 2 of part two of the experiment studies.

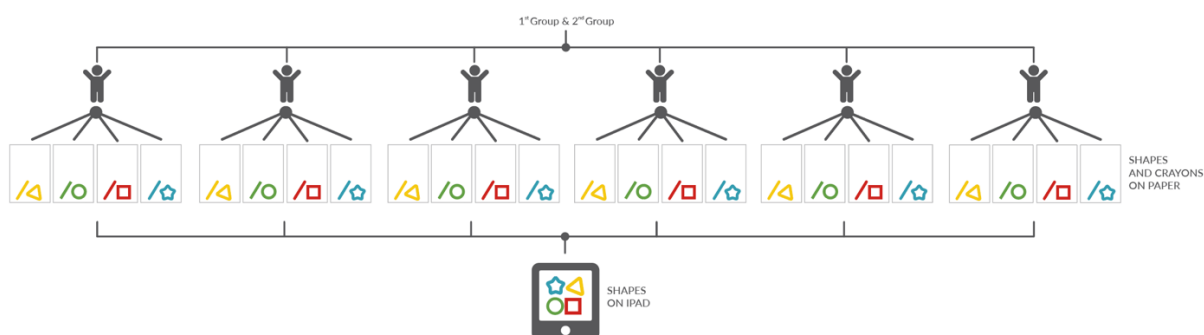


Figure 54 | Free Play - Framework of pilot experimental study approach, two groups, part two.

Table 11 | Structural Explanations – Part 2

FIRST DAY K1 / 3 – 4 years' old	SECOND DAY K2 / 4 – 5 years' old	THIRD DAY K3 / 5 – 6 years' old
- 6 participants total - 15 minutes each session	- 6 participants total - 15 minutes each session	- 6 participants total - 15 minutes each session
First Group // 3 participants 1 Boy - 2 Girls (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (Shapes game platform) + physical pieces	First Group // 3 participants 1 Boy - 2 Girls (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (Shapes game platform) + physical pieces	First Group // 3 participants 2 Boys - 1 Girl (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (Shapes game platform) + physical pieces
Second Group // 3 participants 2 Boys - 1 Girl (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (Shapes game platform) + physical pieces	Second Group // 3 participants 2 Boys - 1 Girl (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (Shapes game platform) + physical pieces	Second Group // 3 participants 1 Boy - 2 Girls (preferable) 1 st Session - print (A4 paper guideline) + physical pieces 2 nd Session - digital (Shapes game platform) + physical pieces

3rd Session Free Play // 6 participants 3 Boys - 3 Girls (preferable) - print (A4 paper guideline) + physical pieces - digital (Shapes game platform) + physical pieces	3rd Session Free Play // 6 participants 3 Boys - 3 Girls (preferable) - print (A4 paper guideline) + physical pieces - digital (Shapes game platform) + physical pieces	3rd Session Free Play // 6 participants 3 Boys - 3 Girls (preferable) - print (A4 paper guideline) + physical pieces - digital (Shapes game platform) + physical pieces
--	--	--

4.7. Conclusion

In this chapter, we explained in detail all the necessary steps we took for setting up our studies in the schools, as well as what the games were, the digital platforms, and the materials used. The structure of our activity sessions follows our snack sessions framework (ref) of collaborative play and creative thinking approaches, utilizing digital and tangible games in a learning environment. In the next chapter, we will explain, in more detail, our structure as well as the outcomes of our experimental studies.

CHAPTER V

STUDY RESULTS, ANALYSIS AND DISCUSSION

CHAPTER V

5. Study Results, Analysis and Discussion (Data)

We have collected a total of 1800 minutes of video & sound data in all three experimental studies. We have analyzed the content observing it based on the following parameters: time, spatial awareness, motor skills, shape recognition, flexible thinking, patience towards the task on hand, fun, difficulty, alternative ways of thinking, and collaboration. There is a wide range of responses, analysis, and answers to these studies. Explanations about the study and the analysis and description of each study are in the sections below.

In our studies, as seen above in chapter four, we used two different game platforms used in education.

The research student was the person collecting the data and, all the participants had preliminary instructions and explanations on how to play the game, before playing the game. We explained what the objective of the game and what was needed from them was.

When using these two platforms, we were careful not giving all the solutions to the participants right away. We wanted them to explore the games on their own, by doing it this way, we could understand if they could deliver the answers we needed.

PART 1

Table 12 | Video & Sound Data - 15 min + 15 min / 15 min + 15 min / 25 min to 30 min

Levels	Instructions	1st School	2nd School	3rd School
K1	5 min - session 1 (3x)	90 min + extra	90 min	90 min
	5 min - session 2 (3x)	sound		
K2	5 min - session 1 (3x)	90 min + extra	90 min	90 min
	5 min - session 2 (3x)	sound		
K3	5/10 min - session 1 (3x)	90 min + extra	90 min	90 min
	5/10 min - session 2 (3x)	sound		
TOTAL	90 min	270 min	270 min	270 min

PART 2

Table 13 | Video & Sound Data - 15 min + 15 min / 15 min + 15 min / 25 min to 30 min

Levels	Instructions	1st School	2nd School	3rd School
K1	5 min - session 1 (3x)	90 min + extra	90 min	90 min
	5 min - session 2 (3x)	sound		
K2	5 min - session 1 (3x)	90 min + extra	90 min	90 min
	5 min - session 2 (3x)	sound		
K3	5/10 min - session 1 (3x)	90 min + extra	90 min	90 min
	5/10 min - session 2 (3x)	sound		
TOTAL	90 min	270 min	270 min	270 min

A total of 1800 minutes of Video & Sound Data collected.

5.1. Descriptive Analysis of the Data

The descriptive analysis was based on the research student and the participant's interactions. Teachers and psychologists were not taken into consideration, and we intentionally left this part out to be explained in the conclusions and analysis section. Below we will explain how teachers and students reacted to each other while playing the game as well as what was their role in these gameplay sessions.

// PILOT EXPERIMENTAL STUDY //

5.1.1. SCHOOL 1 – PUBLIC

PART 1 – Tangram Game

Content Analysis - Kindergarten level 1 – Day 1



Figure 55 | 1st School - Level K1 - Group 1 - Session 1 (Paper game with manipulatives)



Figure 56 | 1st School - Level K1 - Group 1 - Session 2 (Tangram digital game)

Group 1 – session 1 and session 2

In this first session study, the participants were a bit scared of touching and playing the game; the first group was quite shy compared with the second group. We tried first to see how they would react without any outside interference, but soon we found out that they would not touch the game if we did not explain what was needed. What we first tried was to have them relax by carefully explaining what was needed so they would not be afraid to collaborate with us. They did not know the researcher, so they were reluctant to start or even talk. All three participants in the first group were thrilled to be playing the game, but two of them would look at the researcher to see if what they were doing was correct. The researcher told them not to feel any pressure.

One of the participants started to play with the pieces by herself and did not pay attention to what was the goal of the game (task on hand). This was quite interesting, and she was not afraid of exploring beyond the instructions given, which was something that we hoped to observe. What was important to us was how she made alternative connections between the pieces and the puzzle and experimented with different solutions. We asked if she needed help with the game and asked the others, who had already finished if they could help her. Both agreed to help, although one much more open to collaboration than the

other. When they started to help, by placing the pieces correctly, an exciting thing happened, she said that she knew how to complete the game and proceeded to do so by herself.

This means that she was making connections and seeing the relationships between the pieces and eventually finding new solutions/ideas.

Overall all the participants identified the physical pieces, colors, and the puzzle images. They all understood the instructions on how to play the game clearly, but one of them wanted to explore what else could be done with the pieces.

During the second session, the participants got excited and did not hesitate to play with the digital game platform, but they did not understand how the pieces worked in context with the game. They continuously tried to position the pieces directly on the screen (screen was positioned vertically). They did not grasp the spatial/visual relationship between the pieces and the game platform.

They had no trouble with the multi-touch functionality and using their index finger, however by placing the pieces on the screen and having no reaction from the game they got frustrated and eventually just focused on playing with the physical pieces. The collaboration was quite active in this session since they tried to help each other to find a solution.



Figure 57 | 1st School - Level K1 - Group 2 - Session 1
(Paper game with manipulatives)



Figure 58 | 1st School - Level K1 - Group 2 - Session 2
(Tangram digital game)

Group 2 – session 1 and session 2

In the first session, the participants were calmer and quieter. The girl from this group did things faster but had trouble flipping the pieces; one of the boys also had the same problem. They knew how to complete the game with little instructions from the research student. They enjoyed the game and wanted more puzzle images. One of the boys in the first session tried to do something different with the pieces, just like the girl from group 1, he tried to find other creations for the pieces.

In the second session, even though they had a better understanding of how to interact with the digital game platform, they still required help from the research student to find the solution for the puzzle.

Since they were unable to complete it alone, the research student motivated them by placing the paper image in front of the screen so they could place the pieces on the paper in order to complete the puzzle. Even though they became more enthusiastic about this solution, two of them ignored the game platform and tried to do something else on the table with the physical pieces.

Another observation was when two of the boys grabbed the device with the research student and positioned it flat on the table and placed the pieces on top just as they were doing with the paper puzzle guideline. At the same time, they interacted with their index fingers on the screen. They did this for quite some time while the girl kept constructing her shapes on the side and finding new ideas.

Because they understood that the digital puzzle reference was identical to the paper puzzle reference, they asked to play with the paper puzzle again from the first session. They wanted the digital game platform to work the way it was when playing the paper game puzzle.



Figure 59 | 1st School - Level K1 - Group 1 & 2 – Free Play Session (Paper game with manipulatives)



Figure 60 | 1st School - Level K1 - Group 1 & 2 – Free Play Session (Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

The third session consisted of a collaborative play where both groups played with the paper puzzle and the digital game platform.

When they played the paper puzzle, they were focused, collaborating, and happy. Once they switched to the digital puzzle, while some were engaged and played together, the rest were demotivated. After some time, two participants from the first group and one participant from the second group sat down together and played both the paper and digital puzzle at the same time. However, all participants in the third session were unable to complete any of the digital puzzles without the help of the research student or each other. They wanted very much to do it by themselves.

Content Analysis - Kindergarten level 2 – Day 2



Figure 61 | 1st School - Level K2 - Group 1 - Session 1 (Paper game with manipulatives)



Figure 62 | 1st School - Level K2 - Group 1 - Session 2 (Tangram digital game)

Group 1 – session 1 and session 2

These participants, in the first session, completed the puzzle on the sheet of paper quickly. They also tried placing the pieces directly on the table using the paper puzzle as a guide. They only completed one of the puzzles and tried doing other shapes outside of what was instructed. The two girls were always engaged, and the boy was distracted and tried distracting them.

In the second session, they were happy to see the game platform, mentioning that they play with this device at home. They were able to complete two of the digital puzzles by working together. The boy continued distracting the girls, but he was very active in regards to playing the game. One of the girls was calmer when playing with the other girl, together they tried finding the solution for the puzzle.



Figure 63 | 1st School - Level K2 - Group 2 - Session 1
(Paper game with manipulatives)



Figure 64 | 1st School - Level K2 - Group 2 - Session 2
(Tangram digital game)

Group 2 – session 1 and session 2

In this first session, two of the participants were very calm while the other was very active and interfered with the playing of the game. The research student had to be stricter with him. Despite the interference, the digital puzzles were completed. The calmer participants helped the more active participant, who had trouble focusing, finish the puzzle.

In the second session, they all worked together with just one set of pieces to play. They were able to complete various puzzles together despite being a very active session. This group, apart from being one of the most active, they were also one of the most experimental since they already had experience playing with this type of device at home. The most active participant was focused and engaged when playing with the device; he understood the game visually and audibly. In fact, he enjoyed sound so much, and he wanted to hear sound when playing. All of them understood the gameplay and how to play. The calmest participant always collaborated with the others and tried to play each chapter of the game, providing engagement for the girl participant.



Figure 65 | 1st School - Level K2 - Group 1 & 2 - Free Play (Paper game with manipulatives)



Figure 66 | 1st School - Level K2 - Group 1 & 2 – Free Play (Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

In the third session, they played the paper puzzle both individually and together and completed all the puzzles. Some wanted to play with the digital puzzle since most of them were already used to playing this game and wanted something different.

Content Analysis - Kindergarten level 3



Figure 67 | 1st School - Level K3 - Group 1 - Session 1 (Paper game with manipulatives)



Figure 68 | 1st School - Level K3 - Group 1 - Session 2 (Tangram digital game)

Group 1 – session 1 and session 2

In this session, one of the participants required special attention. They all completed the puzzles, with and without the paper. Two participants, a boy and a girl required help from the research student and the other participant to solve the puzzles outside the paper guideline. They managed to complete all the puzzles as well as the bonus puzzle. They mentioned that they really liked to play these kinds of games.

In the second session, the participants were happy with the digital puzzle. Not only did they play collaboratively, helping each other, they also swapped places so each of them could play the puzzle game alone while being aided by the others.



Figure 69 | 1st School - Level K3 - Group 2 - Session 1
(Paper game with manipulatives)



Figure 70 | 1st School - Level K3 - Group 2 - Session 2
(Tangram digital game)

Group 2 – session 1 and session 2

They all completed the puzzles, with and without the paper. Once all the puzzles were completed along with the bonus puzzle, they played on the table without any visual guidelines. They used the physical pieces to create original designs before the second session started. Some had difficulty flipping the pieces.

In the second session, they were able to play the game without issues, and they understood the spatial relationship of the pieces in relation to the game platform. They collaboratively played and swapped places to play individually, helping each other completing the puzzles. This group was calm, focused, and engaged. However, one of the two girls was afraid of failing.



Figure 71 | 1st School - Level K3 - Group 1 & 2
- Free play (Paper game with
manipulatives)



Figure 72 | 1st School - Level K3 - Group 1 & 2 – Free Play
(Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

In the third session, they all played the paper puzzle individually, and together, they completed the puzzles. Only a few wanted to play with the digital puzzle. They only used the digital platform as a guide to doing their puzzles on the table.

5.1.2. SCHOOL 1 – PUBLIC

PART 2 – Shapes Game

Content Analysis - Kindergarten level 1 – Day 1



Figure 73 | 1st School - Level K1 - Group 1 – Session (Paper game with crayons and tangibles)



Figure 74 | 1st School - Level K1 - Group 1 – Session 2 (Shapes digital game)

Group 1 – session 1 and session 2

In this session study, the participants quickly and energetically started drawing with the shapes, they all responded well, and minimum guidance was provided. They all identified the shapes and colors correctly.

When the digital game was introduced, they reacted calmly, and again little guidance was needed since they knew what they had to do and simply follow the instructions of the game. Overall, participation and collaboration were good. One participant was very eager to do it by himself, and he did not let others participate.

In this part of the study, because all participants new the research student, they were more welcoming and more at ease with the situation.

Participants wanted to play more in the digital session and even preferred it to the OSMO session, saying that these pieces were more comfortable to manipulate.



Figure 75 | 1st School - Level K1 - Group 2 – Session 1
(Paper game with crayons and tangibles)



Figure 76 | 1st School - Level K1 - Group 2 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

In this session study, a teaching assistant was brought in to provide a familiar setting for the participants. One of the girl participants completed her tasks quickly, and the other two seemed shy. Compared to the first group, who had a better dynamic flow, this one was more individual, and each participant had their rhythm. However, all participants answered the research student's questions about the color of the crayons and the shapes they were drawing.

In this group, when the digital platform presented, two of the participants started to touch the screen impulsively. The research student had to tell the participants to use the shapes on the screen, this group was not as coordinated as the first, but the curiosity and interest in the game were present. They treasured the moment they were playing the game since they asked to come back later.



Figure 77 | 1st School - Level K1 - Group 1 & 2 – Free Play (Paper game with crayons and tangibles)



Figure 78 | 1st School - Level K1 - Group 1 & 2 – Free Play (Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

When the two groups were combined, there was much energy in the room. One of the boy participants drew with great force on the paper, and he used broad movements. All the boy participants talked while the girl participants sat quietly and used soft movements when drawing. When the digital game was shown, three participants started to fight for possession, two boys and one girl.

The research student had to intervene and verbally calm them down. While this is happening, one boy participant sits patiently waiting, and the remaining two participating girls continue drawing contently on their papers. The research student had to impose a gameplay order for them to start. One girl participant now sits alone, still drawing while the rest focus on the game platform. The five participants all want to play at the same time, and the psychologist had to step in and calm them down. The research student asks the girl participant if she would like to join in; she collects her drawings and answers yes.

Collaboration is observed between four participants, three girls, and one boy; they help each other while the game is passed on to the next participant. Excitement and noise fill the room. At the end of the session, one boy participant displayed frenetic movements.

All participants played the games while most of them preferred the game platform some still preferred the traditional physical connection to the crayons and the tangible objects that still were used for drawing and playing.

Content Analysis - Kindergarten level 2 – Day 2



Figure 79 | 1st School - Level K2 - Group 1 – Session 1
(Paper game with crayons and tangibles)



Figure 80 | 1st School - Level K2 - Group 1 – Session 2
(Shapes digital game)

Group 1 – session 1 and session 2

At the beginning of the session, the research student asked the participants to sit around the table. After being told to sit down, one of the participants grabbed a pencil, the research student asked for the pencil back and told him that the task first needed to be explained. The participant got up and went to play with something else. This participant had ADHD. Both the research student and the psychologist asked the participant to get back to his seat. After the explanation, the participants started to draw on their papers. The boy participant was very energetic, and he kept looking around and getting out of his seat. For the most part, the group worked well, occasionally talking to each other, correctly identifying the shapes and colors.

There was excitement when the digital game was shown, and the participants began to touch the screen impatiently. After some brief guidance from the research student, the participants played in conjunction fairly well and had fun. The boy participant remained energetic throughout the session.



Figure 81 1st School - Level K2 - Group 2 – Session 1
(Paper game with crayons and tangibles)



Figure 82 | 1st School - Level K2 - Group 2 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

In this group the girl participant asked to play with the digital game, the research student explained that the digital game came after the paper game. This group was very chatty, colors and shapes were answered correctly.

When it was time for the digital game the participants remained calm and they played collaboratively.



Figure 83 | 1st School - Level K2 - Group 1 & 2 – Free Play
(Paper game with crayons and tangibles)



Figure 84 | 1st School - Level K2 - Group 2 – Free Play
(Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

When both groups were combined, they rushed to their seats, and some participants were asking for the digital game, the research student reminded them that they would start with pencils and paper first.

The two boy participants quickly finished their drawings while the rest calmly continued at their own pace; they wanted very much to play with the digital game and remained very vocal.

Only when most of the group finished drawing did the research student introduce the digital game, one girl participant remained drawing on her own. When she finished she joined the rest of the group, and they were very energetic and vocal, all wanted to play and were impatient.

The research student had to distribute the game evenly; otherwise, the other participants would not have a chance to play. One girl participant started to play with other things since it wasn't her turn to play.

Content Analysis - Kindergarten level 3 - Day 3



Figure 85 | 1st School - Level K3 - Group 1 – Session 1 (Paper game with crayons and tangibles)



Figure 86 | 1st School - Level K3 - Group 1 – Session 2 (Shapes digital game)

Group 1 – session 1 and session 2

The research student asked the participants to identify shapes and colors to which they answered correctly. One boy participant finished first and sat in his seat, waiting for the other participants to finish. All participants enjoy drawing and coloring. The girl participant was the second to finish, and she also sat patiently, waiting for the last participant to finish.

There was some excitement when the digital game was presented, and the research student gave little instructions before they started, none had ever played this game before. Each participant took their turn, and there was no trampling or hogging, they collaborated well together.



Figure 87 | 1st School - Level K3 - Group 2 – Session 1
(Paper game with crayons and tangibles)



Figure 88 | 1st School - Level K3 - Group 2 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

With this group, the research student started by explaining that this session would present a different game. When each participant had the paper in front of them, one girl participant asked what she could do? The research student answered that the participant could do whatever she feels like doing. This participant was very inquisitive and energetic and enjoyed coloring. The participants knew the shapes and colors.

The research student presented the digital game and explained that they would play collectively and would have to remain calm. Although they overcrowded the screen, it was not aggressive, they played well together, with minor guidance from the research student.



Figure 89 | 1st School - Level K3 - Group 1 & 2 – Free Play (Paper game with crayons and tangibles)



Figure 90 | 1st School - Level K3 - Group 2 – Free Play (Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

In this session, both groups remained relatively calm and finished their coloring effortlessly. One boy participant was given the digital game since he was the first to finish; the others steadily joined once they had completed drawing. The inquisitive participant remained drawing since she enjoyed it so much. She shared her paper with another girl participant. The other participants each tried taking a turn playing, sometimes overcrowding the game, the research student had to keep telling them to remain calm and to share the game. By the end, all participants had played the game.

5.1.3. SCHOOL 2 – PRIVATE

PART 1 – Tangram Game

Content Analysis - Kindergarten level 1 – Day 1



Figure 91 | 2nd School - Level K1 - Group 1 – Session 1
(Paper game with manipulatives)



Figure 92 | 2nd School - Level K1 - Group 1 – Session 2
(Tangram digital game)

Group 1 – session 1 and session 2

The participants started to place the pieces on top of the paper by themselves with some ease. The same result was observed with the second and third paper. While playing some of the participants would answer the research student's questions, the boy participant was the most communicative. The research student asked the participants to combine the shapes on the table while using the paper as a guide. One girl participant had difficulty in completing the task. Little to no difficulty was observed when they had to place the shapes on top of the fourth paper.

The digital game was introduced with some explanation from the research student. Although the participants combined the shapes with ease, one girl participant preferred to use the paper guide instead of the digital game.



Figure 93 | 2nd School - Level K1 - Group 2 – Session 1
(Paper game with manipulatives)



Figure 94 | 2nd School - Level K1 - Group 2 – Session 2
(Tangram digital game)

Group 2 – session 1 and session 2

This group, although slow, completed their tasks with little guidance. These participants also enjoyed playing with the pieces independently from the paper.

The research student also had to explain how the digital game worked. There was also a girl participant who enjoyed playing with the paper more instead of the digital game. At a certain point, all participants started banging the pieces on the table, and they liked the sound.



Figure 95 | 2nd School - Level K1 - Group 1 & 2 – Free Play
(Paper game with manipulatives)



Figure 96 | 2nd School - Level K1 - Group 1 & 2 – Free Play
(Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

When the groups were combined, the participants were chatty and had good energy together. When they completed the games, they felt excited and kept asking for more.

Some of the participants asked for the digital game, and we're very excited to start playing again. But none of them completed a single task even with the assistance of the research student, and they could not agree on a shape. They just played with the pieces without combining them into the desired shapes. At the end of the session, each of them was doing their own thing. Some with the digital game, others with paper — plenty of interaction with each other.

Content Analysis - Kindergarten level 2 – Day 2

Figure 97 | 2nd School - Level K2 - Group 1 – Session 1
(Paper game with manipulatives)



Figure 98 | 2nd School - Level K2 - Group 1 – Session 2
(Tangram digital game)

Group 1 – session 1 and session 2

The participants sat down and started to play right away, without explanation. All the participants were quick. They were very communicative with each other. By the third figure, the two boys completed a figure outside the paper, while the girl was still doing it on top of the paper. When the fourth figure was presented, they went back to putting the pieces on the paper, one of the boys, when finished, started piecing the figure on the table. They liked competing with each other, trying to see who would be first to finish.

The research student presented the game and suggested they play together; they looked at the screen and slowly completed the first figure. Each took a turn in front of the screen trying to complete the figures, and they liked touching the screen and choosing the figures. The research student would help them every so often, explaining how the game worked. They sometimes completed the figures even though it did not align with the sensor. They did not find it boring, and they enjoyed the experience.



Figure 99 | 2nd School - Level K2 - Group 2 – Session 1
(Paper game with manipulatives)



Figure 100 | 2nd School - Level K2 - Group 2 – Session 2
(Tangram digital game)

Group 2 – session 1 and session 2

When the participants sat down, the research student started asking questions, and the girl participant immediately began completing the game, she finished very quickly. One of the boy participants had played this game before, and the other boy participant had never played before. When asked to combine the pieces on the table, without placing them on top of the paper, the difficulty arose. They could not complete the figure and just made constructs of their own. When presented with the next figure, the girl once again finished quickly, the boy who completed before now just played with the pieces and the boy who had some difficulty slowly completed the figure. This was observed again with the next figure, while the boy was taking pieces from the other participants. The girl was the only one who completed the five figures. By the end, the two boys just played with their pieces, not really trying to complete the tasks.

The digital game was presented, and the research student told them to complete the figure on the screen and showed them how to do it. The girl managed to complete the first task, but with the assistance of the research student but by the second figure, she managed to complete one by herself. The two boys played mostly with their pieces while the girl was with the digital game. When it was their turn, they completed the figures even if it did not align with the reflector.



Figure 101 | 2nd School - Level K2 - Group 1 & 2 – Free Play (Paper game with manipulatives)



Figure 102 | 2nd School - Level K2 - Group 1 & 2 – Free Play (Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

All the participants started playing with their pieces, and some were quick, others took their time. Continually conversing with each other and asking for the next figure when they had finished. They were dynamic and well behaved; they would not interfere with the other participants' game.

The digital game was placed in the middle of the table, and half the group tried completing the figures, while the other half was content with just playing with the pieces and making their own constructions. They talked while playing and had fun.

Content Analysis - Kindergarten level 3 - Day 3

Figure 103 | 2nd School - Level K3 - Group 1 – Session 1
(Paper game with manipulatives)



Figure 104 | 2nd School - Level K3 - Group 1 – Session 2
(Tangram digital game)

Group 1 – session 1 and session 2

The research student gave a brief introduction, and the participants began straight away. After they completed the first task, the research student asked some color questions and also asked them to try to assemble the figure on the table instead of on top of the paper. The boy was quick to assemble and helped one of the girls, and the other girl did not complete her figure. For the second figure, the boy finished first, and the girls finished second at the same time.

Again, they were asked to complete it on the table using the paper as a visual guide. This time the boy and one of the girls completed while the other girl did not manage to complete, and the boy helped her again. The third figure again presented no challenge, and when they completed on the table, all managed to assemble it this time. The research student told them to play freely with the pieces and asked questions while they played, some have played with video games, all had played Lego and liked it more than this game. The fourth and fifth figures were easy to complete both on the paper as well as on the table.

There were some adjusting and explanation for the participants, and they did not quite understand at first, they stared and touched the digital game before they started to play. Each participant took a turn in front of the screen, and they all completed the figures, only one of the girls had help from the boy.



Figure 105 | 2nd School - Level K3 - Group 2 – Session 1 (Paper game with manipulatives)

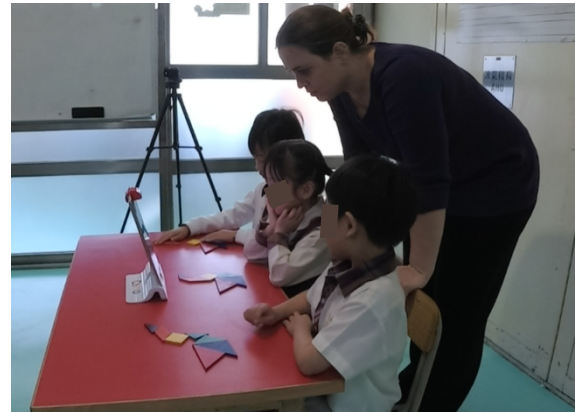


Figure 106 | 2nd School - Level K3 - Group 2 – Session 2 (Tangram digital game)

Group 2 – session 1 and session 2

This group was a bit hesitant to start, and the research student had to tell them that it was ok to start. This group had little difficulty assembling the first figure on the paper and the table. Same for the second figure, both times the two boys were faster than the girl. The research student asked them to play freely, and the two boys placed the shapes horizontally while the girl played with them vertically. Third and fourth figures were also completed without difficulty.

The research student briefly explained the digital game, and they started playing. The girl was first and needed assistance from the research student. One of the boys was second and also needed help. The girl helped him. The last was the other boy who managed to complete the figure with very little assistance.



Figure 107 | 2nd School - Level K3 - Group 1 & 2 – Free Play (Paper game with manipulatives)



Figure 108 | 2nd School - Level K3 - Group 1 & 2 – Free Play (Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

When combined, they were energetic and quick, they knew the figures already from before and even asked for certain ones to play with.

When the digital game was introduced, each took a turn playing, half of the group was looking at the screen, while the other half continued playing with the paper version. At a certain point, the research student placed the game in another position so that the whole group could see the screen. The research student kept encouraging them to play freely with the pieces while they played.

5.1.4. SCHOOL 2 – PRIVATE

PART 2 – Shapes Game

Content Analysis - Kindergarten level 1 – Day 1



Figure 109 | 2nd School - Level K1- Group 1 – Session 1
(Paper game with crayons and tangibles)



Figure 110 | 2nd School - Level K1 - Group 1 – Session 2
(Shapes digital game)

Group 1 – session 1 and session 2

After the research student told the participants that this game was different from before, they started to play. They all wanted to use the shape on their paper, and they would take the Shape from the other participant's hands. Their knowledge of shapes and color was tested, and it was satisfactory. The boy participant kept engaging with one of the girl participants trying to help her with her drawing. Two participants, a boy, and a girl were excited. They banged their crayons on the table, and the psychologist had to tell them to be quiet.

The research student presented the digital game and asked the participants to identify the shapes once more before they started. Each participant had one shape to play with; they played a little hard with the shapes and had to be told to play slower. The participants played calmly throughout the session.



Figure 111 | 2nd School - Level K1 - Group 1 – Session 1
(Paper game with crayons and tangibles)



Figure 112 | 2nd School - Level K1 - Group 1 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

The research student began asking the participants questions regarding colors. While drawing, they would communicate with each other and remain relatively calm throughout.

For the digital game, each participant was given a shape to play. They were excited at the beginning and would slam the shapes on the screen, and the research student had to tell them to do it carefully. The research student was always supervising them during the session. At a certain point, the participants became agitated while they continued to play.



Figure 113 | 2nd School - Level K1 - Group 1 & 2 – Free Play
(Paper game with crayons and tangibles)



Figure 114 | 2nd School - Level K1 - Group 1 & 2 – Free Play
(Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

The participants were very vocal but calm. Although they all enjoyed drawing, there was one girl participant that enjoyed it a little more than the others.

The participants became more energetic when the research student showed the digital game, and they had to be reminded that they needed to share. Once more, extra attention was needed for the combined groups. The research student organized the participants into smaller groups so that the session would go smoothly. One of the girl participants was a bit emotional, but it soon passed. By the end of the session, one girl participant asked if she could draw, the research student handed her paper and crayons. By the end of the session, the participants had calmed down.

Content Analysis - Kindergarten level 2 – Day 2

Figure 115 | 2nd School - Level K2 - Group 1 – Session 1
(Paper game with pieces)



Figure 116 | 2nd School - Level K2 - Group 1 – Session 2
(Shapes digital game)

Group 1 – session 1 and session 2

The research student began the session with some questions regarding shapes and colors. When identifying the first shape, the girl participant said it was a fidget spinner instead of a triangle. For the rest of the shapes, they had no problem identifying them correctly. Again, this group was very communicative. One of the boys drew on the girl's paper, and she got a bit upset, the research student intervened and found a solution which the girl found satisfying, and the boy apologized. They were very creative when drawing and coloring, and they used the shapes repeatedly to fill the paper. The research student asked them if they wanted to play with the digital game to which they replied yes.

After explaining the game, each participant used a shape and repeatedly tapped on the screen with it. The research student had to tell them to calm down and take a turn playing. One boy participant got bored quickly by a limited number of shapes. He would like to play with shapes in the form of tanks. He enjoyed the previous game more (Tangram).



Figure 117 | 2nd School - Level K2 - Group 2 – Session 1
(Paper game with pieces)



Figure 118 | 2nd School - Level K2 - Group 2 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

The research student once again explained to the group that this was a different game and continued by asking shapes and color questions, to which they answered correctly. When asked, they all responded that they liked digital games more, compared to the drawing. One boy participant was very excited, and he started to drum loudly on the table. The same boy drew a girl figure with the circle given, and with the square, he drew his mother. The girl next to him also drew her mother due to him drawing his mother. For his last drawing, he drew a Police Officer. The other boy participant said that stars were hard to draw; the research student suggested he use the star shape as help. He proceeded to draw many stars.

The participants felt comfortable with the digital game, and they calmly selected the game. The girl asked to have the circle shape at the start. The research student gave them each a turn with the game. The first boy was tapping the shapes a bit hard on the screen. He was told to do it slowly and with less force. The other boy was fine when he played, the girl started playing but shortly after the first boy took the game away from her. The research student selected another level and gave each one a go. This time around, they did not interfere much with who was playing. The girl was excited since she did not play much before. The research student selected the last level, and this time they played together taking turns with each one holding one shape.



Figure 119 | 2nd School - Level K2 - Group 1 & 2 – Free Play (Paper game with pieces)



Figure 120 | 2nd School - Level K2 - Group 1 & 2 – Free Play (Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

Both groups entered the session very chatty; they sat down and began drawing and coloring. While they drew, they continued talking with each other, sometimes too loudly, the research student had to remind them to murmur. The research student asked them which game they like more. The majority answered that they like the digital game; one boy even said he liked the digital game from before (Tangram).

They became more excited when it was time for the digital game, once one of the participants started to play, they slowly quieted down and stared at the screen. Each took a turn to play. The research student stayed with the participant who was playing. The ones who had already played remained calm, but the ones who were waiting for their turn were very anxious. When the game reached the last two participants they were all playing together, the research student placed the game at the center of the table so they would play together. By the end, two boys started to play with each other while the other four participants played collaboratively. At the end of the session, the research student asked them which digital games they liked more, and all answered that they liked both games, except for the boy who still maintained that he liked the first game (Tangram) more.

Content Analysis - Kindergarten level 3 - Day 3

Figure 121 | 2nd School - Level K3 - Group 1 – Session 1
(Paper game with pieces)



Figure 122 | 2nd School - Level K3 - Group 1 – Session 1
(Shapes digital game)

Group 1 – session 1 and session 2

The research student explained to the group that this session would start with a drawing, and at the end, they would play with the digital game, and they answered some colors and shapes questions while they drew. One of the boys stood up and search for more colors to draw with, and the research student gave some more colors. When asked about what they liked more, what they were doing now and the digital game they played before, the two boys answered that they liked the current game, while the girl said that she liked the other game more. The research student continued asking questions throughout, to which the participants answered correctly. In the end, one of the boys started to stack the shapes on top of each other and placed the crayons inside. The girl joined in.

The research student told the group that to play the digital game, they had to remain calm. They placed all the shapes on the screen. The research student decided to give each of the participants a turn to play. The next level was calmer because they could only place one shape at a time. Another level was introduced, and they had fun while they interacted with their fingers on the screen, they played together and played individually as well. When asked, they said they enjoyed this game.



Figure 123 | 2nd School - Level K3 - Group 2 – Session 1
(Paper game with pieces)



Figure 124 | 2nd School - Level K3 - Group 2 – Session 1
(Shapes digital game)

Group 2 – session 1 and session 2

The research student told the group that they would be playing a different game and proceeded to ask them the color and shapes questions. This group likes to play video games more than drawing. This group shared the shapes calmly between them while they drew.

For the digital game, each participant was given shape, and they calmly took a turn placing the respective shape on the screen while they played together. For the final level, they each took a turn playing, one participant had control of all the shapes; the others provided verbal aid.



Figure 125 | 2nd School - Level K3 - Group 1 & 2 – Free Play (Paper game with pieces)



Figure 126 | 2nd School - Level K3 - Group 1 & 2 – Free Play (Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

Before they started, the research student told the groups that they are together to see how they will interact with each other. They drew very quickly so that they could move on to the digital game, but still wanted to finish drawing, and they did not hand in any unfinished paper.

The research student was apparent at the beginning, for them to play with the digital game, they will have to remain calm, and if they start to misbehave the game will be taken away. First, they played together, and they were very chatty and excited. One of the girls continued to draw and color while the rest played with the digital game. They continued to play using their fingers, each taking a turn. The research student would moderate them accordingly. By the end, some of the participants asked if they could draw some more, now there were three drawing and three playing.

5.1.5. SCHOOL 3 – MIXED

PART 1 – Tangram Game

Content Analysis - Kindergarten level 1 – Day 1

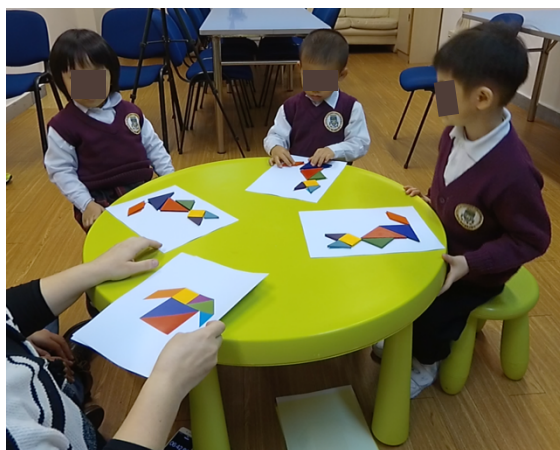


Figure 127 | 3rd School - Level K1 - Group 1 – Session 1
(Paper game with manipulatives)



Figure 128 | 3rd School - Level K1 - Group 1 – Session 1
(Tangram digital game)

Group 1 – session 1 and session 2

This group had a research assistant to help with the translation. Both researchers started by explaining what they were going to do. Two participants started slowly to place the pieces on the paper, and the third participant watched and followed the other actions. One of the boys looked comfortable and concentrated while playing; the other two kept looking at the others to see if they were playing correctly. The participants were very soft-spoken and serene. By the second figure, they had learned what to do and were a bit faster. The researchers would ask them questions throughout; they would answer very quietly. The next figures were also assembled with little effort.

The researchers carefully explained how to play the digital game, they would play on the table, but they would also try to place the pieces on the screen, and they would slide off. At first, the research student let them continue doing what they were doing but slowly stepped in and gently showed them how the game worked. The participants took turns playing while the research student gently helped them. The first boy participant was the slowest, the other boy and girl were a bit faster. In the end, the research student asked them which game they enjoyed more, and they said they liked the digital game more.



Figure 129 | 3rd School - Level K1 - Group 2 – Session 1
(Paper game with manipulatives)



Figure 130 | 3rd School - Level K1 - Group 2 – Session 1
(Tangram digital game)

Group 2 – session 1 and session 2

In this session, there were only two participants, and the other was sick. In this group, the girl participant started to assemble the figure on the table, using the paper as a guide, the research student did not ask her to do this. Naturally, the boy participant was asked to try and do it like the girl. When the girl completed the figure, she started to assemble on the paper. For the following figures, they completed them on the paper.

The participants took turns playing with the digital game while the research student gave some guidance. When it was the girl's turn, she chose the rabbit figure, a very popular figure chosen by participants, and she was quick in completing the task. Again, when asked, the participants liked the digital game more than the paper version. In the end, both participants played together, helping each one another.



Figure 131 | 3rd School - Level K1 - Group 2 – Session 1
(Paper game with manipulatives)



Figure 132 | 3rd School - Level K1 - Group 2 – Session 1
(Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

The group sat down, they looked happy and dynamic, they picked which figures they would like to do and they completed them much faster. The group was more comfortable and chattier.

For the digital game, the participants played collaboratively while looking at the screen. One of the girl participants still had difficulty with some of the figures. While they played, they would answer questions related to the colors of the shapes. They went through many figures, each had different complexities, but there was a boy who was always slower in completing the tasks. Again, the researchers asked if they liked the digital game more or the paper version to which they responded that they liked the digital game more. By the end, when they were in free play, one of the girl participants felt tired, and it was decided to stop the session.

Content Analysis - Kindergarten level 2 – Day 2

Figure 133 | 3rd School - Level K2 - Group 1 – Session 1 (Paper game with manipulatives)



Figure 134 | 3rd School - Level K2 - Group 1 – Session 1 (Tangram digital game)

Group 1 – session 1 and session 2

Two of the participants were familiar with this game, and they played it at home. The girl participant did not know the game but had no difficulty playing it. She even improvised a bit. She altered the design of the figure by placing a few pieces differently. When asked to assemble on the table, they each created different figures than the one on the paper. The girl continued improvising, she would not recreate the figure but instead gave it a creative twist; she only assembled the last figure correctly. The two boy participants continued assembling the figure on the paper and would only deviate when asked to assemble on the table.

The digital game proved to be a bit difficult, and they tried aligning the pieces but could not get it right so the figures were changed and they assembled the figures. Also, the researchers would place the digital game in front of the pieces and try to align them.



Figure 135 | 3rd School - Level K2 - Group 2 – Session 1 (Paper game with manipulatives)



Figure 136 | 3rd School - Level K2 - Group 2 – Session 1 (Tangram digital game)

Group 2 – session 1 and session 2

In this group, the boy participant had played this game before, and he played at home. The participants were quick and communicative. They were hesitant at first when the research student asked them to assemble on the table, but after the second figure, some participants tried it. When the participants had gone through all the figures, they wanted to continue to play, so the research student gave them back the figures from before.

Before they started playing the digital game, a brief explanation was given by the research assistant. The boy participant said that he had played with digital games before. He was quite chatty about it. They each took turns in front of the screen, with some assistance every now and then.



Figure 137 | 3rd School - Level K2 - Group 1 & 2 – Free Play (Paper game with manipulatives)



Figure 138 | 3rd School - Level K2 - Group 1 & 2 – Free Play (Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

When combined, some of the participants wanted to finish first and were very vocal about it. Every time they finished a figure, they would play without the paper and construct on the table. They communicated a lot with each other as well as with the research assistant while playing. By the end, two participants started to play on the floor.

When they started to play the digital game, one of the girl participants was still playing on the floor by herself. One boy participant grabbed the digital game so he could align it with his figure, but the research student grabbed it back saying that it was for everyone to see. As a rule, whoever completed the figure first would get to choose the next figure. The boy who was very vocal throughout was told to help the other participants. By the end, another girl participant joined the girl who was still on the floor, and they would play freely and talk with the research assistant. At the very end of the session, all but two boys went to play on the floor.

Content Analysis - Kindergarten level 3 - Day 3



Figure 139 | 3rd School - Level K3 - Group 1 – Session 1
(Paper game with manipulatives)



Figure 140 | 3rd School - Level K2 - Group 1 – Session 1
(Tangram Digital Game)

Group 1 – session 1 and session 2

The research student gave brief instructions, and they started to play. The participants were very calm and quiet and remained so throughout. The participants assembled all the puzzle both on top of the paper, and on the table, they present no issues.

For the digital game, each participant took a turn playing. They remained calm throughout the session.



Figure 141 | 3rd School - Level K3 - Group 2 – Session 1 (Paper game with manipulatives)

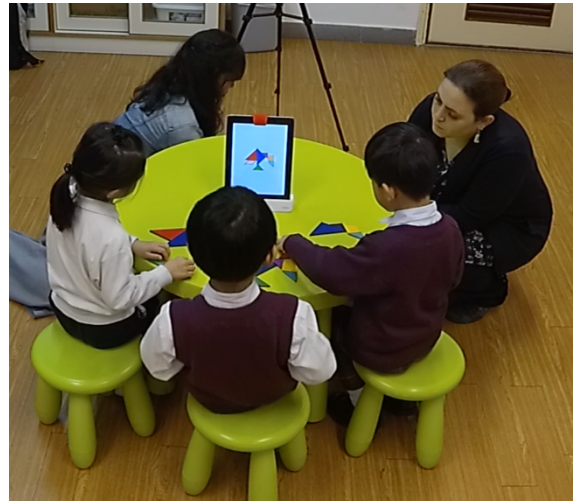


Figure 142 | 3rd School - Level K3 - Group 2 – Session 1 (Tangram digital game)

Group 2 – session 1 and session 2

The participants were able to complete the puzzle on top of the paper, as well as on top of the table, and they presented no issues doing this. The participants remained calm and spoke very little, only speaking when to answer questions.

Each participant took a turn playing with the digital game. The research student gave very little aid.



Figure 143 | 3rd School - Level K3 - Group 1 & 2 – Free Play (Paper game with manipulatives)



Figure 144 | 3rd School - Level K3 - Group 1 & 2 – Free Play (Tangram digital game)

Group 1 & 2 – Free Play Session – Collaboration

The participants seemed very happy when they sat down to play, and as opposed to when they were separated, combined, they became very commutative and energetic. They assembled the figures based on the paper, and they also assembled some shapes that the research student suggested.

They became even more agitated when the research student introduced the digital game, but they gradually calmed down when they started to play. The participants took turns playing, they would mostly follow the game, and some would create different shapes while waiting their turn.

5.1.6. SCHOOL 3 – MIXED

PART 2 – Shapes Game

Content Analysis - Kindergarten level 1 – Day 1



Figure 145 | 3rd School - Level K1 - Group 1 – Session 1
(Paper game with crayons and tangibles)



Figure 146 | 3rd School - Level K1 - Group 1 – Session 2
(Shapes digital game)

Group 1 – session 1 and session 2

The researchers started by explaining to the participants that this session would consist of a different game than before when handing the papers, the participants would get asked different questions regarding colors and preferences. Before they started drawing, they had to guess the shape and grab the correct colored crayon from the research student. The participants would color the shapes and start to draw other things on the same paper, and they would get more creative as it went on. The girl participant finished first and sat patiently, waiting, to look at the others.

The researchers explained and demonstrated how the digital game worked, each participant was given shape, and they would use it accordingly. The girl participant was the most active and vocal of them and seemed very pleased when it was her turn. They would correctly guess the names of the animals presented in the game.



Figure 147 | 3rd School - Level K1 - Group 2 – Session 1
(Paper game with crayons and tangibles)



Figure 148 | 3rd School - Level K1 - Group 2 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

This session only had two participants, a boy, and a girl. The standard questions were asked, colors, and shapes, they answered correctly. They stayed calm and reasonably quiet throughout the session.

Little instructions were given to the participants regarding the digital game; again, they remained quiet and played calmly until the end of the session.



Figure 149 | 3rd School - Level K1 - Group 1 & 2 – Free Play
(Paper game with crayons and tangibles)



Figure 150 | 3rd School - Level K1 - Group 1 & 2 – Free Play
(Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

Both groups were joined, a total of five participants due to the missing participant. They sat down and started drawing, using the shapes and coloring with crayons. They spoke to the research assistant, they seemed happy and having fun.

For the digital game, each participant had one shape and would take a turn playing, and they would switch that shapes between them until everyone had a turn with a different shape. They were dynamic and chatty while they played, and had little interference from the research student.

Content Analysis - Kindergarten level 2 – Day 2



Figure 151 | 3rd School - Level K2 - Group 1 – Session 1
(Paper game with crayons and tangibles)



Figure 152 | 3rd School - Level K2 - Group 1 – Session 2
(Shapes digital game)

Group 1 – session 1 and session 2

The research student started by explaining to the participants that they could draw whatever they liked. One of the boy participants was very chatty. When asked if they liked to draw, two boy participants answered that they liked to draw and that they draw on tablets as well.

When the research student introduced the digital game, one of the boy participants said that he didn't want to play but soon changed his mind. Each had a shape and would take turns playing. They were very agitated and vocal and stayed that way through the whole game.



Figure 153 | 3rd School - Level K2 - Group 2 – Session 1
(Paper game with crayons and tangibles)



Figure 154 | 3rd School - Level K2 - Group 2 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

The research student started by asking the participants what the name of the shapes and their corresponding colors, and that they were free to draw whatever they wanted. Although the participants were vocal and asked many questions, the boy participant was the one who communicated the most.

When the research student presented the digital game, the boy participant seemed very anxious to start playing. He remained very vocal and energetic throughout. Each had a shape and played accordingly with the shape they had. At a certain point in the game, the boy asked to switch shapes with the other participants.



Figure 155 | 3rd School - Level K2 - Group 1 & 2 – Free Play (Paper game with crayons and tangibles)



Figure 156 | 3rd School - Level K2 - Group 1 & 2 – Free Play (Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

When combined, the participants were very active, sharing and switching shapes and crayons. Initially, two boy participants stopped drawing after a while and just wanted to wait for the digital game, but they eventually asked to continue to draw.

When they started to play the digital game, two participants remained drawing. After some time, the four participants started to play a little more aggressively by slamming the shapes on the screen, so the research student told them to take turns playing and to stay calm while playing.

Content Analysis - Kindergarten level 3 - Day 3



Figure 157 | 3rd School - Level K3 - Group 1 – Session 1
(Paper game with crayons and tangibles)



Figure 158 | 3rd School - Level K3 - Group 1 – Session 2
(Shapes digital game)

Group 1 – session 1 and session 2

The participants seemed a little shy and reluctant at first. The research student told them it was all right to start drawing. One of the girl participants was very curious. She always was looking at the research student to see what novelty would be presented.

The research student started by telling the participants to listen to the instructions first and that each would be given a shape to play with. They enjoyed drawing, but there was more energy and communication when interacting with the digital game.



Figure 159 | 3rd School - Level K3 - Group 2 – Session 1
(Paper game with crayons and tangibles)



Figure 160 | 3rd School - Level K3 - Group 2 – Session 2
(Shapes digital game)

Group 2 – session 1 and session 2

The two boy participants started drawing right away, but the girl participant took her time to start, and when she did, she was slow at it. She eventually got into the same rhythm as the other two.

When the participants started to play the digital game, the excitement rose considerably, especially in the case of one of the boy participants. He became very agitated in his seat and very vocal, he would often miss his turn due to playing with his shape, he would spin it on the table, and being distracted.



Figure 161 | 3rd School - Level K3 - Group 1 – Free Play (Paper game with crayons and tangibles)



Figure 162 | 3rd School - Level K3 - Group 1 & 2 – Free Play (Shapes digital game)

Group 1 & 2 – Free Play Session – Collaboration

The participants were very commutative towards each other, they were dynamic, sharing the colored crayons without much fuss. The research student presented the option for the participants to choose if they wanted to continue drawing or to play with the digital game. Two participants, a boy, and a girl chose to continue drawing.

The other four participants took turns playing with the digital game, and they were very vocal when playing. The girl participant who was drawing decided to play the digital game. At a certain time, the research student had to intervene because the participants were playing too hard with the shapes; they were told to calm down. The boy participant remained drawing until the end of the session.

5.2. Data Results & Analysis

We have analyzed the content observed based on the following parameters below (Table 14) to help us answer our research questions as well as comprehend how we could apply specific stipulations to our framework so it would be possible to implement the classroom environment.

Table 14 | Parameters used when observing their actions – reactions – motions during the studies.

Motor skills - movements and actions (manipulation of objects) – “learned ability to cause a predetermined movement outcome with maximum certainty.”

Hand-eye-coordination - “coordinated eye movement with the hand movement and processing of visual input.”

Understanding spatial recognition – “spatial perception also consists of understanding the relationship between two objects when there is a change in their position in space.”

Thinking outside the box – (flexible thinking)

Timings – the time participants take to complete an activity and task on hand.

Recognition of shapes; objects; colors – if the participants recognize all the objects, shapes and colors that are in front of them

Awareness and understanding the task on hand – understand what was expected from them.

Asking why / how / what if... – if during the sessions they ask any questions.

Storytelling – imagination – creation of a different world.

Collaboration between peers – if there is collaboration amongst them in order to complete the task on hand.

Language barriers – they spoke at least 3 different languages.

Creative play – were they open to creative, out of the box play, free play...

Promptly, we will talk about the outcomes related to each level and school. We based our observation levels on the difficulty levels used in one of the game platforms.

Our results and data are based solely on our observations and parameters.

In the first part of the session, we created and printed in an A4 paper, the Tangram puzzles mimicking the game. We first started slowly with the participants by asking them to follow the figure (paper's guideline) in order for them to complete the puzzle, we first asked them to do the puzzle on top of the figure and then outside the paper, on the table.

After they have completed around four to five puzzles within a few minutes, we moved to the digital game platform where each of them would play the game puzzle, they took turns and while one would play and the other would "*wait*", they would use the screen figure as the guideline for them to also create they puzzle on their own, on the table without the paper guideline.

Various times, during the puzzle game, participants, would create different things with the wood pieces or redo the printed/figure puzzles again, or look at the screen and do the same thing as the other was doing. The distractions that we believe were "distractions" were more creative than whatever they were doing related to the game; it showed that they had more ideas than others. They would create houses, flowers, cats, trees, it was quite exciting and fun to watch, since they were getting in their comfort zone with the pieces and trying to play and create new things.

In the second part of the study, once again, having in consideration that we only had one mobile tablet, we created a session following the first part of the study. However, this time, we did not create all the shapes of the game; we used the pieces collaboratively so that they could share the four shaped / manipulatives amongst themselves. This time we gave them a blank white paper where they could use the shapes as they please, in this part we added an extra element in the experiment to also mimic some of the gameplay features of the game as well as provide something familiar to them that could be used to draw by using the shaped pieces, and then move to the digital learning platform. Each one could only use one of the pieces to draw one or more drawings in a piece of paper, one shape, one blank paper for them to do whatever they would please with them, and then change amongst them the shape and use another paper to do something else.

Once they were playing with the digital game platform, each of them had only one piece, they played together and followed the gameplay and used the shapes accordingly. This way, all participants could play at the same time and share the pieces amongst them. Normally it would take a bit more time, but since they knew that something new was coming next, they would try to finish as fast as possible.

We did not show them the digital platform until they have completed this part of the session so they would not feel anxious.

5.2.1. Analysis of the Parameters – SCHOOL1

Part 1- The descriptive analysis is in section 5.1.2. of the thesis

Table 15 | School 1 – Part 1 - Session 1 - Paper/Puzzle Tangram

K1	K2	K3	Parameters	
1	4	4	Motor Skills - movements and actions (manipulation of objects)	1
2	3	3	Hand-Eye- Coordination	2
2	4	4	Understanding Spatial Recognition	3
2	3	3	Thinking outside the box (flexible thinking)	4
2	3	3	Timings	5
3	4	4	Recognition of shapes; objects; colors	6
2	4	4	Awareness and understanding the task on hand	7
2	3	3	Asking Why / How / What if...	8
2	3	4	Storytelling - Imagination - Creation of a different world	9
2	3	2	Collaboration between peers	10
3	4	4	Language barriers - at least 3 different languages...	11
2	3	4	Creative Play	12

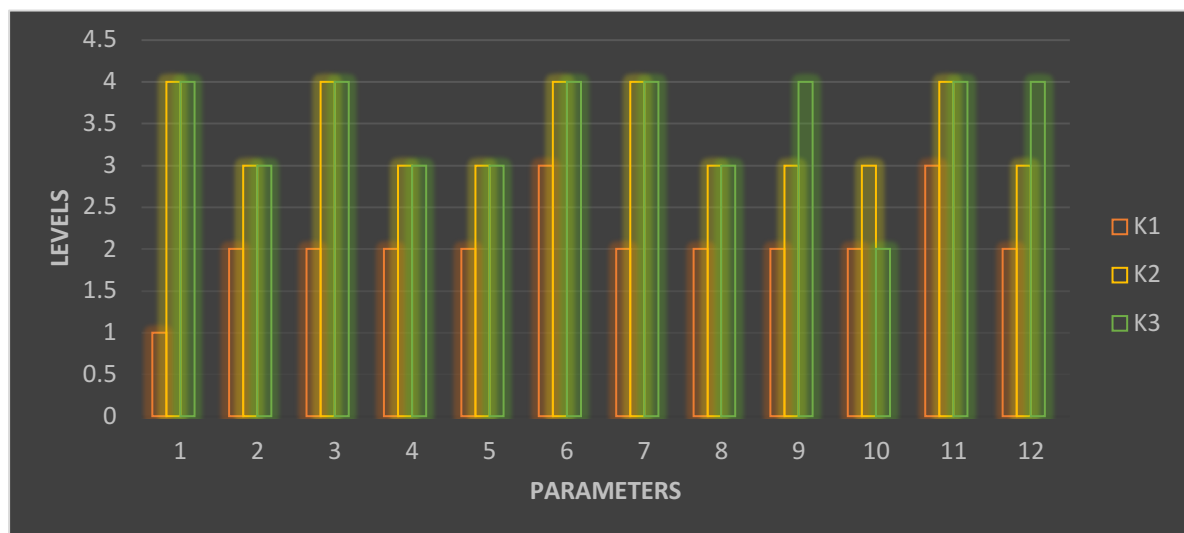


Figure 163 | School 1 – Part 1 - Session 2 – Tangram Platform

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Table 16 | School 1 – Part 1 - Session 2 – Tangram Platform

K1	K2	K3	Parameters	
1	4	4	Motor Skills - movements and actions (manipulation of objects)	1
2	3	3	Hand-Eye-Coordination	2
1	4	4	Understanding Spatial Recognition	3
2	2	4	Thinking outside the box (flexible thinking)	4
1	3	3	Timings	5
3	4	4	Recognition of shapes; objects; colors	6
2	3	4	Awareness and understanding the task on hand	7
1	3	4	Asking Why / How / What if...	8
2	2	2	Storytelling - Imagination - Creation of a different world	9
2	2	4	Collaboration between peers	10
3	3	4	Language barriers - at least 3 different languages...	11
2	3	3	Creative Play	12

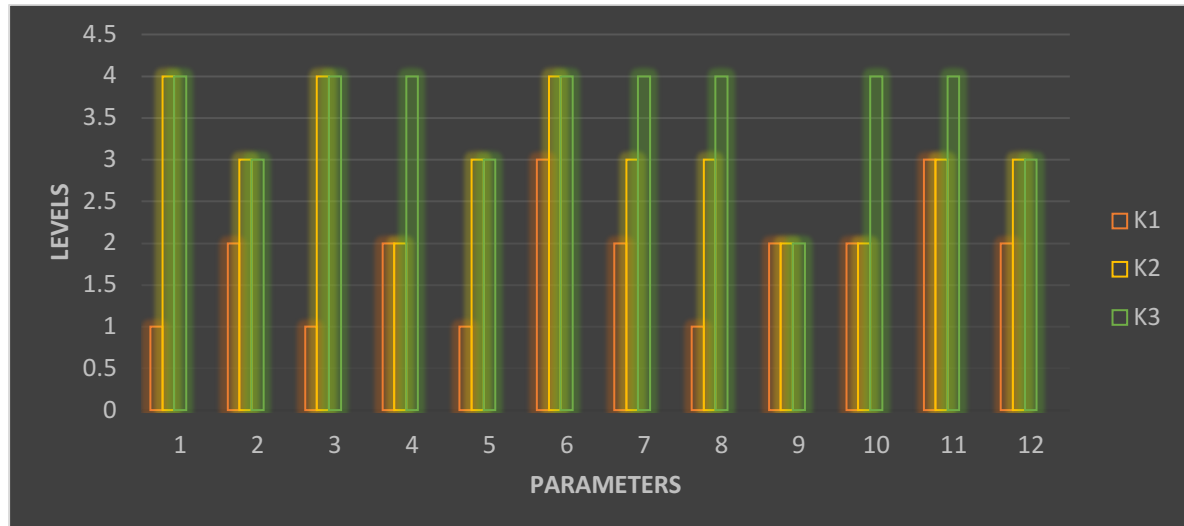


Figure 164 | School 1 – Part 1 - Session 2 – Tangram Platform

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

1 - Motor Skills - movements and actions (manipulation of objects)

K1 had more difficulty in this parameter since they mostly tried to do things faster, but were unsuccessful. Sometimes pieces would fall on the ground, and they would have some issues turning the pieces. This relates to their physical development. K2 and K3 could do it with almost no issues.

2 - Hand-Eye-Coordination

K1 also had more difficulty in this parameter, due to their age. However, K2 and K3 also presented difficulties but not to the extent of K1. In the session, K2 and K3 would try and assemble the puzzle pieces on the table and the top of the paper... However, in session two, it was more difficult for them to follow the guideline on the screen and follow the correct position of the pieces. Some of them would still prefer to create the puzzle on the table, ignoring the guide.

3 - Understanding Spatial Recognition

They all shared the same difficulty in this area. However, the difficulty was more significant for those who were younger. Most of the K1 and K2 students would put the piece directly on the screen, assuming that the screen would recognize the piece, instead of on the table, allowing for the reflector to read the piece. This was the most common issue.

4 - Thinking outside the box (flexible thinking)

K1 and K2 had the most difficulty with this. Some of the participants from this group managed to think outside the box... some would create different puzzles on the table as well as flip and rotate the pieces to find different solutions. They would do this on their own without any guidance from the research student. K3, however, would also think outside of the box more frequently since they would not only do the puzzles on the paper and the screen, but they would also do other things outside the paper and only on the table.

5 – Timings

K1 took a bit more time to finish the tasks on hand compared to K2 and K3. K1 would frequently think about what they should do and how they should do it.

6 - Recognition of shapes; objects; colors

Most of the participants were exceptional in this parameter; only a few from K1 had problems identifying the colors and shapes.

7 - Awareness and understanding the task on hand

As expected, K1 showed more difficulty, since they would get distracted and do something else with the pieces instead of the puzzles, however it was always interesting to observe their actions and what kind of things they were creating.

8 - Asking Why / How / What if...

K1 did not question much, and they would do it, K2 was almost identical, they just wanted to play. K3 would ask questions and talk a lot about the game and why they like to play.

9 - Storytelling - Imagination - Creation of a different world

In terms of storytelling about the game itself, they would not be so open when they were in session two, however in session one, they would talk a lot more about the puzzle pieces. Because they would create different things with the puzzle pieces, they would sometimes create stories for those creations. This was quite interesting and fun. K1 also presented some apprehension in talking... so not all participants were open to this.

10 - Collaboration between peers

In session one participants would be a bit more collaborative than in session two, K3 seemed a bit more collaborative.

11 - Language barriers - at least 3 different languages...

In session one, most of the Kindergarten levels were excellent. Though, in session two, some difficulties arose. We believe that this was due to the sounds and music being emitted from the game that was not very clear. Therefore, some participants had issues understanding the game — no language guides.

12 - Creative Play

In session one, participants were more open to creative play than in session two, although this changed in the free-play session.

School 1 – Part 1 - Session 3 – Free-Play

Concerning the Free-Play session, all participants were very relaxed and open to play, more so than in session one and session two. We believe that once we gave them more freedom, but with minimum guides, they were more open to new ways of interacting with each other through play. When we gave them the opportunity for it, they went for it. What we noticed was that they got very excited when the digital platform was on the table, and that was sometimes a bit difficult to manage. Despite this, when the necessary guidance was given, the creative play was boosted by the digital/tangible platform.

Part 2 – The descriptive analysis is in section 5.1.3. of the thesis.

Table 17 | Session 2 – Shapes – Paper - Crayons

K1	K2	K3	Parameters	
2	3	4	Motor Skills - movements and actions (manipulation of objects)	1
3	3	3	Hand-Eye- Coordination	2
1	4	4	Understanding Spatial Recognition	3
2	2	4	Thinking outside the box (flexible thinking)	4
2	2	3	Timings	5
3	4	4	Recognition of shapes; objects; colors	6
3	4	4	Awareness and understanding the task on hand	7
1	2	3	Asking Why / How / What if...	8
2	3	4	Storytelling - Imagination - Creation of a different world	9
2	3	3	Collaboration between peers	10
3	4	4	Language barriers - at least 3 different languages...	11
4	4	4	Creative Play	12

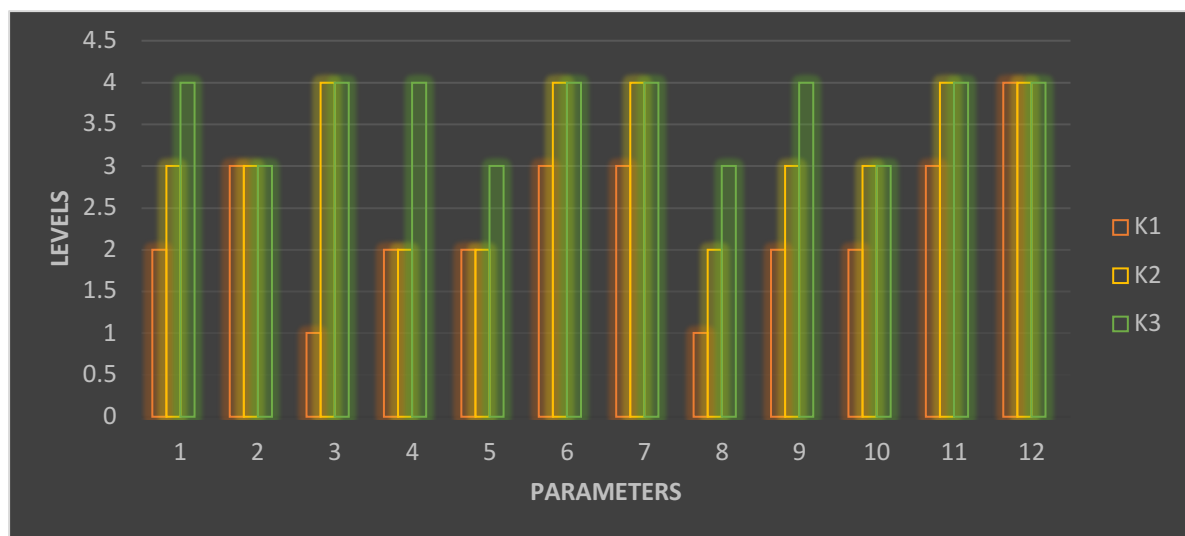


Figure 165 | School 1 - Part 2 - Session 1

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Table 18 | Session 2 – Shapes Platform

K1	K2	K3	Parameters	
2	4	4	Motor Skills - movements and actions (manipulation of objects)	1
2	4	4	Hand-Eye- Coordination	2
3	4	4	Understanding Spatial Recognition	3
1	2	3	Thinking outside the box (flexible thinking)	4
3	4	4	Timings	5
4	4	4	Recognition of shapes; objects; colors	6
3	4	4	Awareness and understanding the task on hand	7
3	4	4	Asking Why / How / What if...	8
2	3	3	Storytelling - Imagination - Creation of a different world	9
3	3	3	Collaboration between peers	10
4	4	4	Language barriers - at least 3 different languages...	11
2	3	3	Creative Play	12

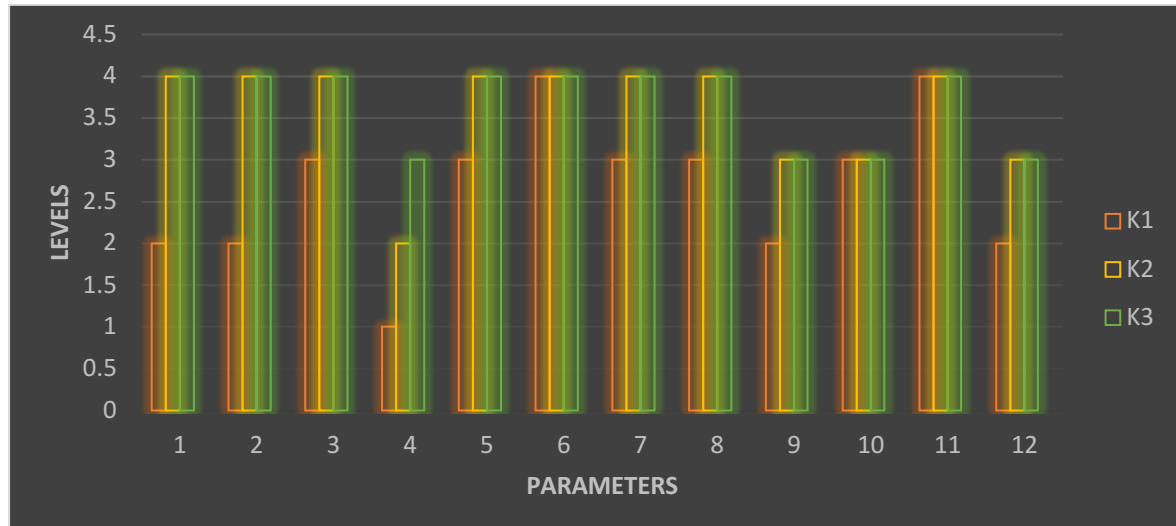


Figure 166 | School 1 - Part 2 - Session 2

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 – Medium | 4 – Easy (felt comfortable)

1 - Motor Skills - movements and actions (manipulation of objects)

It was evident that K1 had more difficulty in this parameter. Nonetheless, this was a more accessible game, and so it had simpler things to deliver. The drawing was something that they had already been doing for quite some time, so it was more comfortable, and following the shapes and painting in and outside the shape required fewer demanding movements.

2 - Hand-Eye-Coordination

They had fewer issues, and we believe that it was because session one and session two were more familiarized with the objects and felt at ease to play with these objects. It was a game that was very intuitive and more understanding for K1 and K2. For K3, it was reasonably straightforward.

3 - Understanding Spatial Recognition

All levels had fewer issues since the platform also provided more guidance and was more intuitive; they would only get the tangible objects on the top of the tablet.

4 - Thinking outside the box (flexible thinking)

Participants were more open in session one than session two since the first activity provided them with more flexible thinking. Session two also provided areas to think outside of the box, especially the faces and bodies game, where they would have to create their characters.

5 – Timings

In session one, K1 participants took a bit more time because they would frequently stop, draw, go back to drawing, and so on..., even so, they still did it within the timings needed. K2 and K3 were quite good, and they always wanted to draw more in session one and play more in session two.

6 - Recognition of shapes; objects; colors

Most of the participants would be fine in this parameter.

7 - Awareness and understanding the task on hand

It was quite straight forward for all participants to understand it.

8 - Asking Why / How / What if...

Participants were more inquisitive during session two than session one. Due to the nature of the tasks, session one was very straightforward.

9 - Storytelling - Imagination - Creation of a different world

K1 remained constant in both sessions, K2 and K3 did better but K3 stood out in session one, they were creative.

10 - Collaboration between peers

Both sessions were leveled, not too much but not too little either, with K1 having less cooperation in session one.

11 - Language barriers - at least 3 different languages...

All the participants showed good language understanding.

12 - Creative Play

In session one and session two, participants were excited and open to new ways of interaction, this activity and game provided a more creative environment, having in consideration that they had more flexibility with the type of games they were playing.

School 1 – Part 1 - Session 3 – Free-Play

In this session, all participants were very excited to play more, and this session was different from the first free-play session of part one, participants were even more open to creative behaviors as well as these kinds of sessions, they were more playful, focused on the task on hand as well as more collaborative.

5.2.2. Analysis of the Parameters – SCHOOL 2

Part 1- Descriptive analysis in section 5.1.4. of the thesis.

Table 19 | School 2 – Part 1 - Session 1 – Paper/Puzzle Tangram

K1	K2	K3	Parameters	
1	3	4	Motor Skills - movements and actions (manipulation of objects)	1
2	3	3	Hand-Eye- Coordination	2
2	3	4	Understanding Spatial Recognition	3
1	3	3	Thinking outside the box (flexible thinking)	4
1	3	4	Timings	5
2	4	4	Recognition of shapes; objects; colors	6
2	3	4	Awareness and understanding the task on hand	7
1	3	3	Asking Why / How / What if...	8
1	2	4	Storytelling - Imagination - Creation of a different world	9
2	3	4	Collaboration between peers	10
2	4	4	Language barriers - at least 3 different languages...	11
2	3	4	Creative Play	12

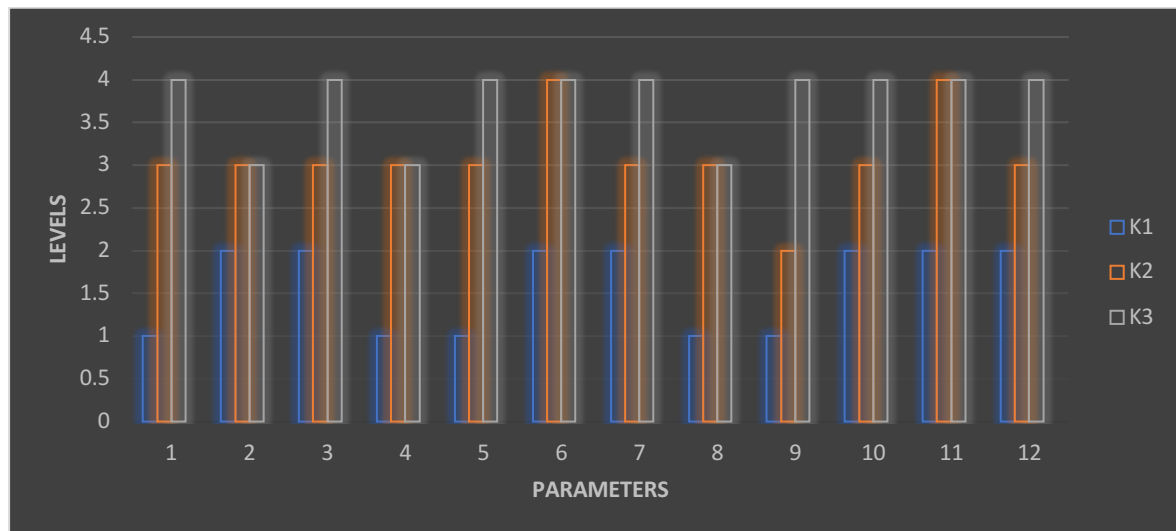


Figure 167 | School 2 – Part 1 - Session 1 – Paper/Puzzle Tangram

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Table 20 | School 2 – Part 1 - Session 2 – Tangram Platform

K1	K2	K3	Parameters	
1	3	4	Motor Skills - movements and actions (manipulation of objects)	1
2	2	3	Hand-Eye- Coordination	2
1	3	4	Understanding Spatial Recognition	3
1	3	4	Thinking outside the box (flexible thinking)	4
1	3	4	Timings	5
3	4	4	Recognition of shapes; objects; colors	6
2	3	4	Awareness and understanding the task on hand	7
1	3	2	Asking Why / How / What if...	8
1	3	3	Storytelling - Imagination - Creation of a different world	9
1	4	4	Collaboration between peers	10
1	4	4	Language barriers - at least 3 different languages...	11
2	3	4	Creative Play	12

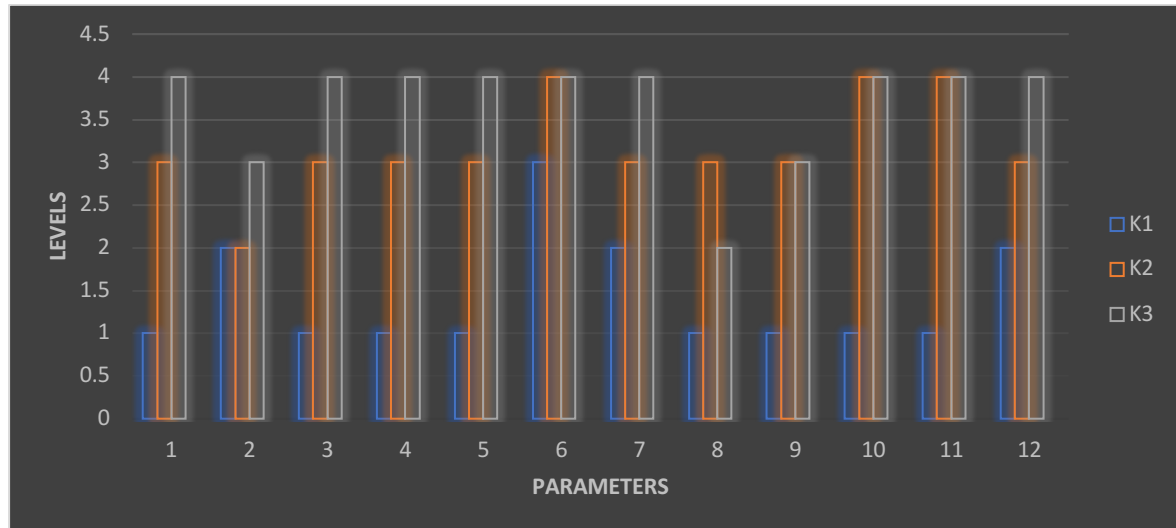


Figure 168 | School 2 – Part 1 - Session 2 – Tangram Game

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

1 - Motor Skills - movements and actions (manipulation of objects)

K1 had more difficulty in this parameter since they sometimes tried to do things faster and could not do it. K2 and K3 could do it with almost no issues.

2 - Hand-Eye-Coordination

K1 had more difficulty in this parameter as well, due to their age. However, K2 also had some difficulties, but not as much. We believe that K3 was slightly better but still had some difficulties.

3 - Understanding Spatial Recognition

K1 had more difficulty in this parameter in session two, compared with session one. K2 and K3 were excellent in both sessions.

4 - Thinking outside the box (flexible thinking)

K1 had the most difficulty in session one and session two, they did not interact much nor come up with very new ideas, and in session one is where they usually have more flexibility in thinking. Related to K2 and K3, they were more or less good, although K3 was quite straightforward in finishing the puzzles in session one so they could move on to the next task, that they did not implement any other new ideas with the pieces of the puzzle.

5 – Timings

K1 took a bit more time to finish the tasks on hand than K2 and K3.

6 - Recognition of shapes; objects; colors

Most of the participants were exceptional in this parameter. K1 had problems identifying the colors and shapes, and they had more difficulty in session one than in session two. Once they recognized the shapes of session one in the digital game, session two was more relaxed.

7 - Awareness and understanding the task on hand

I believe that all of them understood the tasks on hand, apart from K1 who had some difficulties.

8 - Asking Why / How / What if...

K1 did not talk much. K2 and K3 were more open to questioning, especially K2, they were quite expressive.

9 - Storytelling - Imagination - Creation of a different world

In terms of storytelling, K3 was quite expressive and even played with the pieces in session one and session two in various ways. K1 and K2 were great, and some participants were quite expressive regarding storytelling, in relation to the puzzle pieces. They would construct new things and tell a story.

10 - Collaboration between peers

In session one, K1 was more playful together and helped each other, however in session two, and they were a bit less. About K2 and K3, they were quite open to collaboration.

11 - Language barriers - at least 3 different languages...

K2 and K3 were fine with the language barriers. However, K1 had some difficulties with the digital platform. They could not understand the sound/music guidelines.

12 - Creative Play

Taking into consideration the participant's age, we believe that the creative play was excellent. However, the younger ones were sometimes better than, the older ones, bringing to the table more playful creative behaviors than others. The game and the activities provided gratification at the end of each session, so this was also important for all participants, and that boosted creative behaviors.

School 2 – Part 1 - Session 3 – Free-Play

All participants were engaged in the free-play session. This session provided more time for improvements, and also it helped the flow of new creative ways of completing the tasks on hand. The collaboration was quite high. In free-play sessions, we always observed some collaboration, but in this school, they were more helpful to one another than usual, K2, and K3 were more open to this.

Part 2 – The descriptive analysis is in section 5.1.5. of the thesis.

Table 21 | School 2 – Part 2 - Session 2 – Shapes – Paper - Crayons

K1	K2	K3	Parameters	
1	3	4	Motor Skills - movements and actions (manipulation of objects)	1
2	3	3	Hand-Eye- Coordination	2
1	3	4	Understanding Spatial Recognition	3
2	2	3	Thinking outside the box (flexible thinking)	4
1	2	3	Timings	5
3	4	4	Recognition of shapes; objects; colors	6
3	4	4	Awareness and understanding the task on hand	7
1	1	2	Asking Why / How / What if...	8
1	3	4	Storytelling - Imagination - Creation of a different world	9
2	3	4	Collaboration between peers	10
2	4	4	Language barriers - at least 3 different languages...	11
3	3	4	Creative Play	12

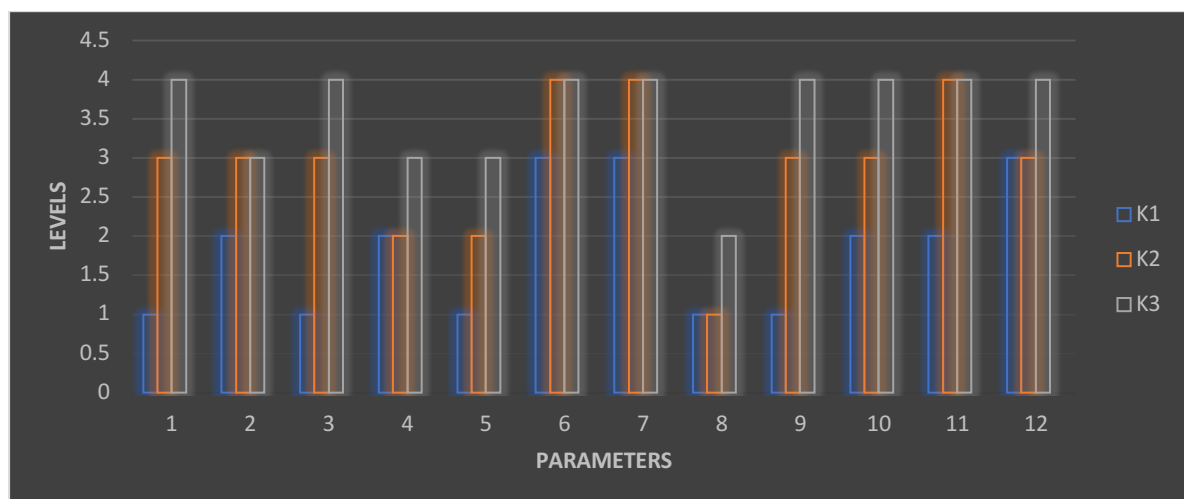


Figure 169 | School 2 – Part 2 - Session 1 – Shapes – Paper – Crayons

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Table 22 | School 2 – Part 2 - Session 2 – Shapes Platform

K1	K2	K3	Parameters	
1	3	4	Motor Skills - movements and actions (manipulation of objects)	1
2	3	4	Hand-Eye- Coordination	2
2	3	4	Understanding Spatial Recognition	3
1	2	3	Thinking outside the box (flexible thinking)	4
2	3	3	Timings	5
4	4	4	Recognition of shapes; objects; colors	6
3	4	4	Awareness and understanding the task on hand	7
3	3	4	Asking Why / How / What if...	8
1	2	3	Storytelling - Imagination - Creation of a different world	9
3	4	4	Collaboration between peers	10
3	4	4	Language barriers - at least 3 different languages...	11
3	3	4	Creative Play	12

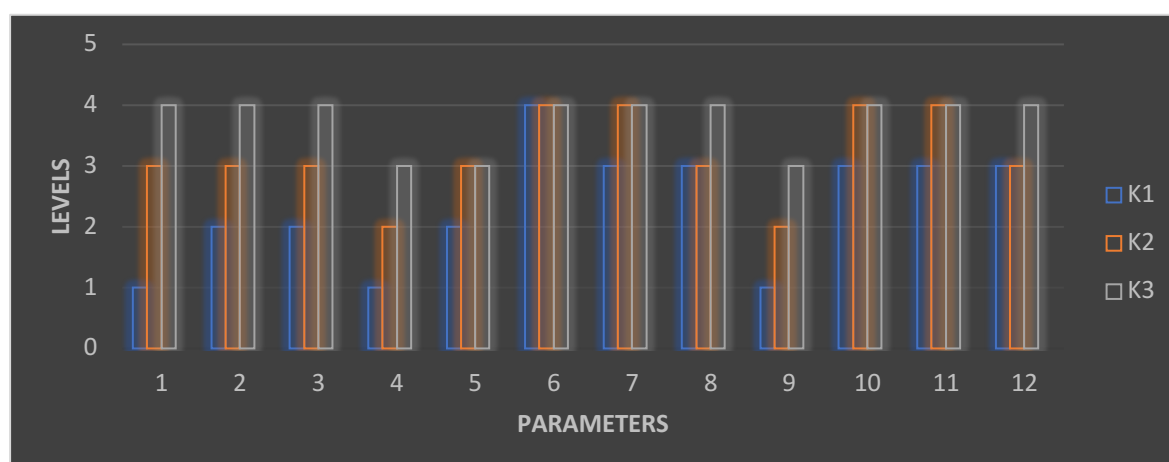


Figure 170 | School 2 – Part 2 - Session 2 – Shapes Platform

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

1 - Motor Skills - movements and actions (manipulation of objects)

K1 showed the same level of difficulty in both sessions. K2 was slightly better and remained consistent through both sessions, with K3 displaying the better results, in both sessions as well.

2 - Hand-Eye-Coordination

K1 had more difficulties and K3 performed better in session two than in session one. K2 was average.

3 - Understanding Spatial Recognition

K1 had the most trouble, especially in session one, they did slightly better in session two. K2 and K3 fared better and remained consistent in both sessions.

4 - Thinking outside the box (flexible thinking)

K1 and K2 had low results, with K1 performing better in session one. K3 did better.

5 – Timings

In session one, K1 and K2 participants took longer because they would regularly pause the activity. K3 was good, they showed interest in both sessions.

6 - Recognition of shapes; objects; colors

Most of the participants would be fine in this parameter, with K1 being slightly lower in session one.

7 - Awareness and understanding the task on hand

All participants demonstrated a good understanding.

8 - Asking Why / How / What if...

The participants were more active and inquisitive in session one compared to session two.

9 - Storytelling - Imagination - Creation of a different world

Session one provided better freedom for creativity, with K3 having higher capacity. In session two, the creativity was restricted by the game, so the levels are lower with K1 being the lowest in both sessions.

10 - Collaboration between peers

Collaboration was good in session one and improved quite considerably in session two.

11 - Language barriers - at least 3 different languages...

All participants understood what was being communicated, with K1 having some issues in session one but felt more comfortable when it came to session two.

12 - Creative Play

In both sessions, the participants were excited, the activities provided a creative environment with flexibility. K3 performed better than K1 and K2.

School 2 – Part 2 - Session 3 – Free-Play

In this session, all participants were more engaged to play, compared with the first free-play session of part 1, participants were even more open to creative behaviors as well as these kinds of sessions, they were more focused on the task on hand as well as more collaborative. One other thing that we noticed was that because they felt more comfortable with these kinds of game setting, they were also more active and playful.

5.2.3. Analysis of the Parameters – SCHOOL 3

Part 1- Descriptive analysis in section 5.1.6. of the thesis.

Table 23 | School 3 – Part 1 - Session 1 – Paper/Puzzle Tangram

K1	K2	K3	Parameters	
2	3	4	Motor Skills - movements and actions (manipulation of objects)	1
2	4	4	Hand-Eye- Coordination	2
2	3	4	Understanding Spatial Recognition	3
2	3	4	Thinking outside the box (flexible thinking)	4
2	3	4	Timings	5
2	4	4	Recognition of shapes; objects; colors	6
2	4	4	Awareness and understanding the task on hand	7
1	3	3	Asking Why / How / What if...	8
1	3	4	Storytelling - Imagination - Creation of a different world	9
2	3	4	Collaboration between peers	10
2	4	4	Language barriers - at least 3 different languages...	11
3	3	4	Creative Play	12

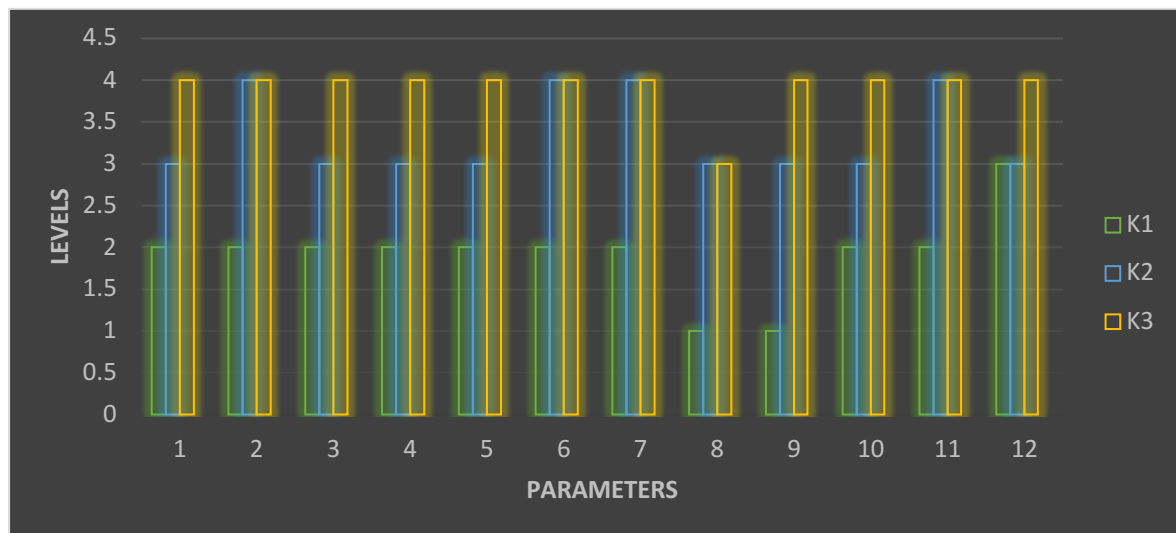


Figure 171 | School 3 – Part 1 - Session 1 – Paper/Puzzle Tangram

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Table 24 | School 3 – Part 1 - Session 2 – Tangram Platform

K1	K2	K3	Parameters	
3	4	4	Motor Skills - movements and actions (manipulation of objects)	1
2	4	4	Hand-Eye- Coordination	2
2	4	4	Understanding Spatial Recognition	3
2	3	4	Thinking outside the box (flexible thinking)	4
2	4	4	Timings	5
3	4	4	Recognition of shapes; objects; colors	6
2	4	4	Awareness and understanding the task on hand	7
1	3	2	Asking Why / How / What if...	8
1	3	4	Storytelling - Imagination - Creation of a different world	9
2	3	4	Collaboration between peers	10
3	4	4	Language barriers - at least 3 different languages...	11
3	3	4	Creative Play	12

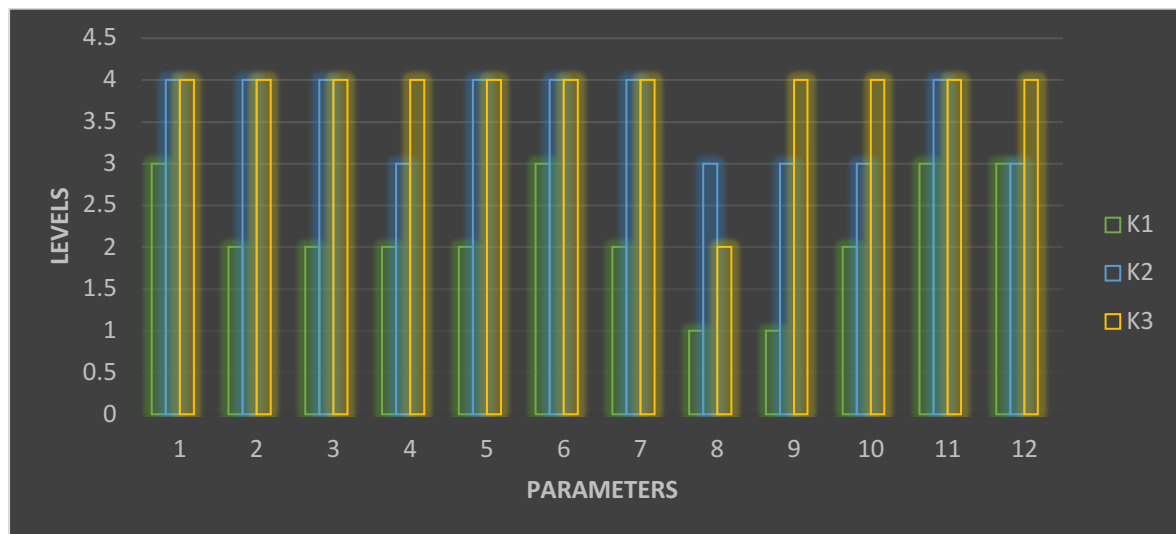


Figure 172 | School 3 – Part 1 - Session 2 – Tangram Platform

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

1 - Motor Skills - movements and actions (manipulation of objects)

K3 had no issues, K2 had some issues in session one but got better in session two. K1 showed some difficulties in session one but performed better in session two.

2 - Hand-Eye-Coordination

K2 and K3 had great results in both sessions with K1 remaining constant throughout.

3 - Understanding Spatial Recognition

K1 had some issues in this parameter in both sessions. K2 and K3 were good throughout, with K2 improving in session two.

4 - Thinking outside the box (flexible thinking)

In both sessions, K1 had the most difficulty, K2 was average and K3 performed better than the rest.

5 – Timings

K1 took longer to complete the tasks than K2 and K3.

6 - Recognition of shapes; objects; colors

The participants performed well in this parameter.

7 - Awareness and understanding the task on hand

Most participants understood the tasks presented. K1 had some difficulties.

8 - Asking Why / How / What if...

K2 and K3 were more communicative than K1 but K2 remained expressive during session two.

9 - Storytelling - Imagination - Creation of a different world

In terms of storytelling K3 was very expressive. K1 and K2 were ok.

10 - Collaboration between peers

In both sessions K1 was ok, K2 did better and K3 was the most open to collaboration.

11 - Language barriers - at least 3 different languages...

All participants displayed good language skills, K1 had some issues in session one but did better in session two.

12 - Creative Play

All participants were good with K3 being better.

School 3 – Part 1 - Session 3 – Free-Play

Participants were engaged in the free-play session. This session provides more time for improvements, and it also helps in the flow of new creative ways of completing the tasks on hand. The collaboration was more actively seen.

Part 2 - Descriptive analysis in section 5.1.7. of the thesis.

Table 25 | School 3 - Part 2 - Session 1 – Shapes – Paper – Crayons

K1	K2	K3	Parameters	
2	3	4	Motor Skills - movements and actions (manipulation of objects)	1
2	3	4	Hand-Eye- Coordination	2
2	3	4	Understanding Spatial Recognition	3
3	3	4	Thinking outside the box (flexible thinking)	4
1	4	3	Timings	5
3	4	4	Recognition of shapes; objects; colors	6
3	4	4	Awareness and understanding the task on hand	7
1	3	3	Asking Why / How / What if...	8
1	3	4	Storytelling - Imagination - Creation of a different world	9
1	3	3	Collaboration between peers	10
2	4	4	Language barriers - at least 3 different languages...	11
2	3	4	Creative Play	12

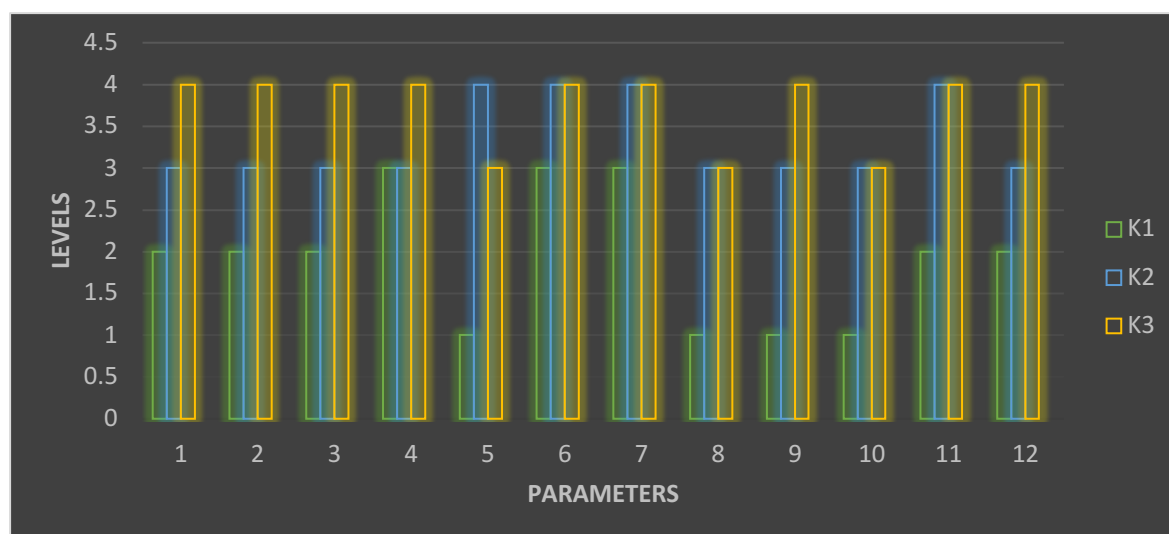


Figure 173 | School 3 - Part 2 - Session 1 – Shapes – Paper – Crayons

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 – Medium | 4 – Easy (felt comfortable)

Table 26 | School 3 - Part 2 - Session 2 – Shapes Platform

K1	K2	K3	Parameters	
2	4	4	Motor Skills - movements and actions (manipulation of objects)	1
2	3	4	Hand-Eye- Coordination	2
2	3	4	Understanding Spatial Recognition	3
1	3	3	Thinking outside the box (flexible thinking)	4
2	3	4	Timings	5
4	4	4	Recognition of shapes; objects; colors	6
3	4	4	Awareness and understanding the task on hand	7
2	2	4	Asking Why / How / What if...	8
1	2	3	Storytelling - Imagination - Creation of a different world	9
2	3	4	Collaboration between peers	10
2	4	4	Language barriers - at least 3 different languages...	11
3	3	4	Creative Play	12

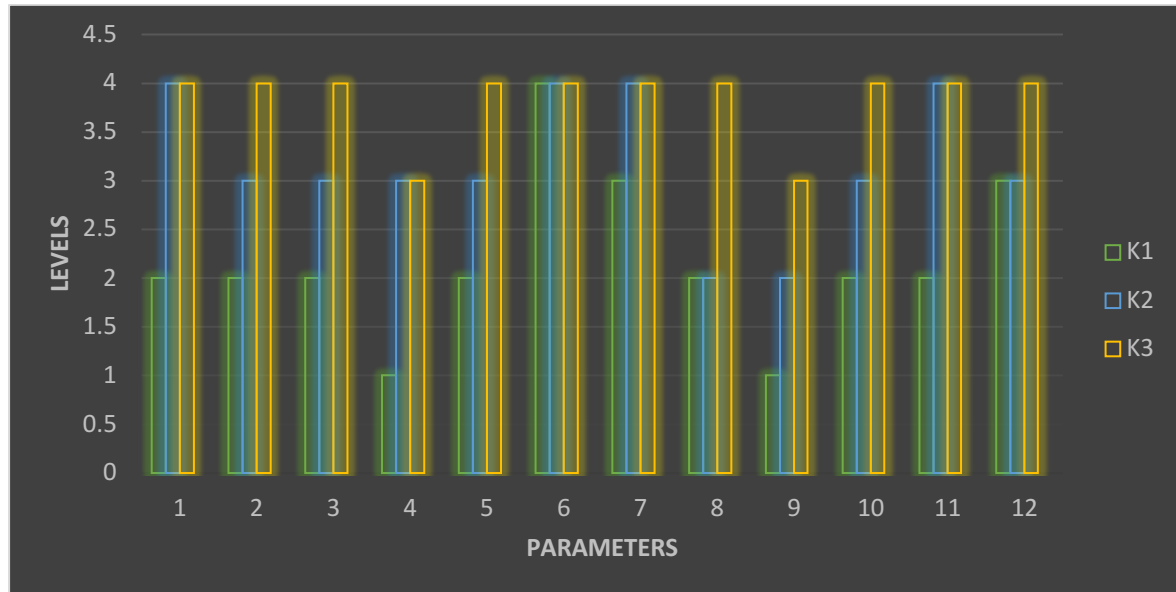


Figure 174 | School 3 - Part 2 - Session 2 – Shapes Platform

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

1 - Motor Skills - movements and actions (manipulation of objects)

K1 had more difficulties, K2 and K3 were fine. K2 got better in session two.

2 - Hand-Eye-Coordination

In both sessions, K1 had some issues, K2 was ok and K3 did the best.

3 - Understanding Spatial Recognition

In both sessions, K1 presented the most issues, while K2 was ok and K3 did the best.

4 - Thinking outside the box (flexible thinking)

Session one had better results than session two. K1 struggled the most.

5 – Timings

K2 did good in both sessions, K3 did better in session two as did K1.

6 - Recognition of shapes; objects; colors

Most of the participants did fine in this parameter.

7 - Awareness and understanding the task on hand

All participants understood the tasks.

8 - Asking Why / How / What if...

Session one was pretty quiet while session two the participants opened a bit more with K3 being the standout.

9 - Storytelling - Imagination - Creation of a different world

In terms of storytelling, the game in session two presented little room for creativity. Most of the participants did well in session one, except for K1.

10 - Collaboration between peers

Participants remained the same when collaborating in both sessions, except for K3. They were more collaborative in session two.

11 - Language barriers - at least 3 different languages...

K1 and K2 participants understood well, with K1 having some issues.

12 - Creative Play

Session two saw more creativity than in session one, this was wonderful.

School 3 – Part 2 - Session 3 – Free-Play

Part 2 was always more fun for them, and creative behaviors were observed. They even asked us to come back again so they could have a bit of fun every day. Collaboration was observed, as well.

5.2.4. Comparison between schools

Part 1 – Session 1

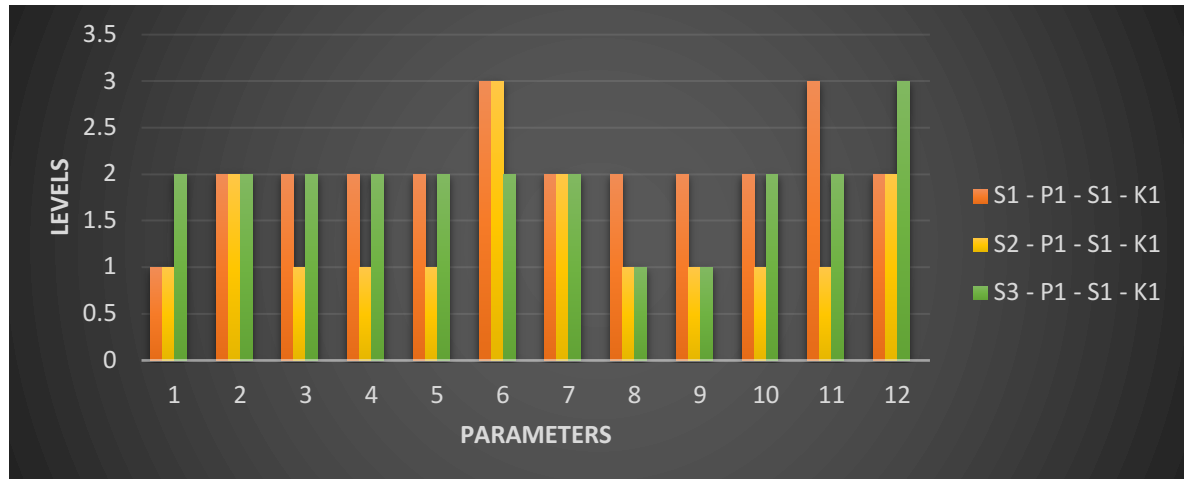


Figure 175 | 3 Schools - Part 1 - Session 1 - K1

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Most of the K1 level participants were more or less at the same level, although in the creative play, school three was stronger.

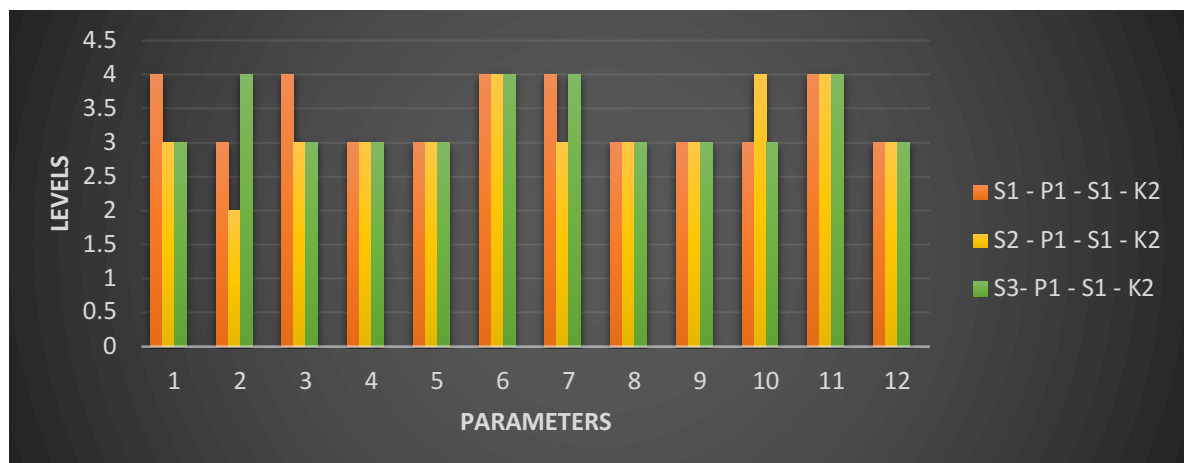


Figure 176 | 3 Schools - Part 1 - Session 1 - K2

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Most of the K2 level participants were more a less at the same level, although in some cases school one was more prominent. But creative play was the same throughout.

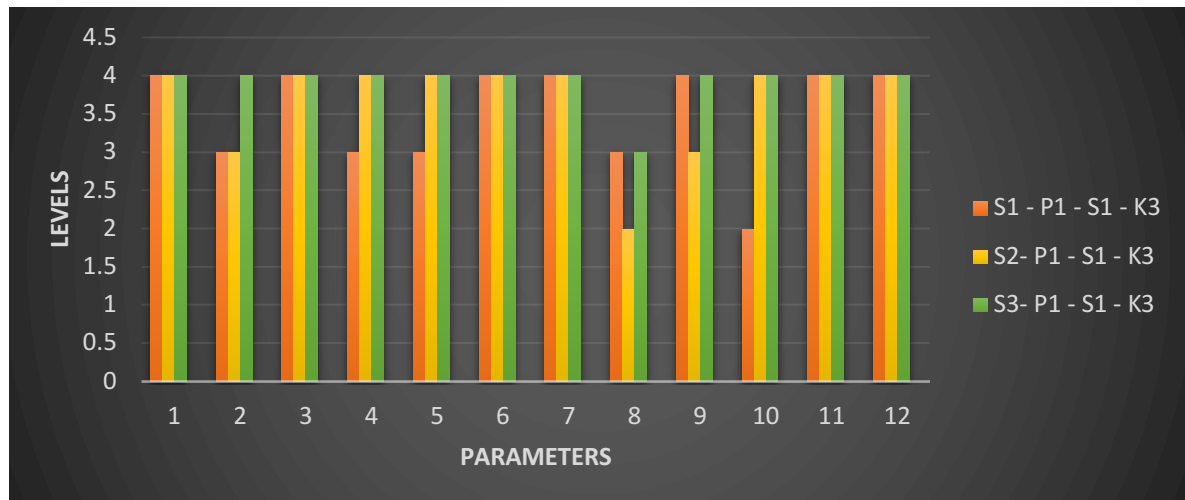


Figure 177 | 3 Schools - Part 1 - Session 1 - K3

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

It is evident that K3 of the third school was stronger in most of the cases, but most importantly the participants' openness for creative play was the same and thinking outside of the box within the task on hand was quite interesting as well.

Part 1 – Session 2

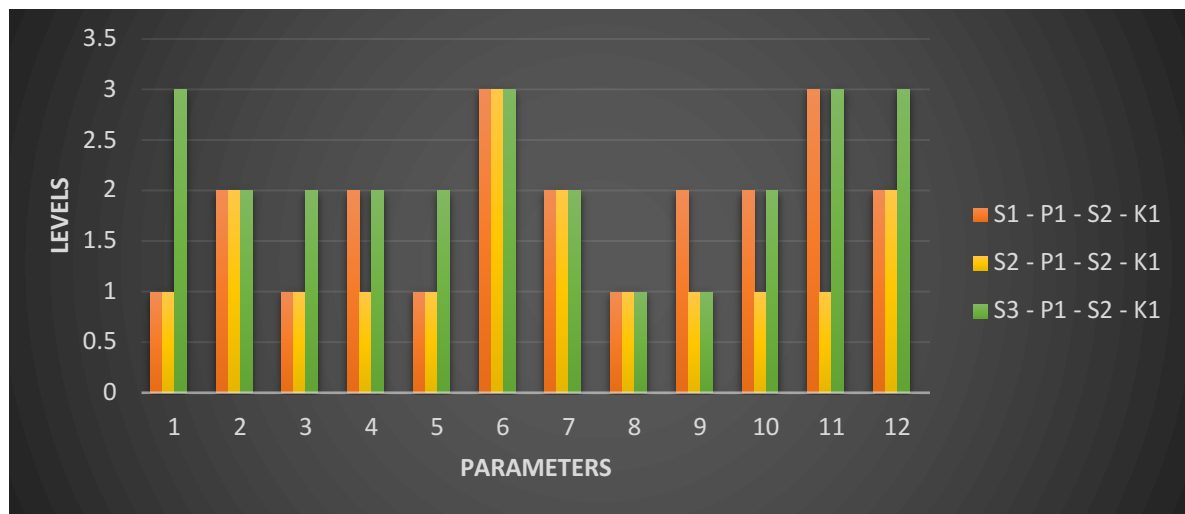


Figure 178 | 3 Schools - Part 1 - Session 2 - K1

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Most of the K1 level participants were more or less at the same level, although in the third school, they were more active and aware of the game shapes and so they played more actively.

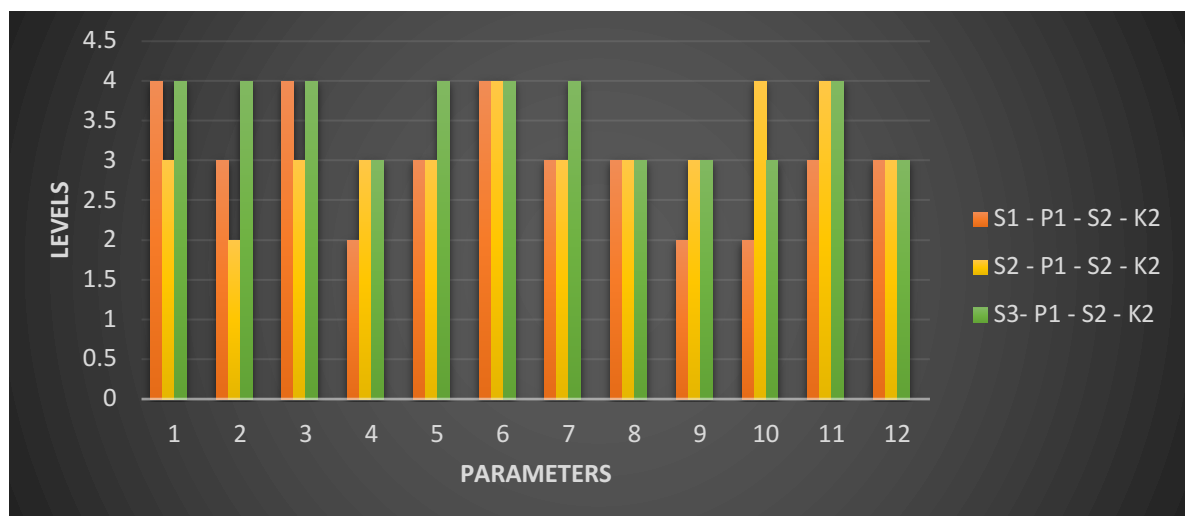


Figure 179 | 3 Schools - Part 1 - Session 2 - K2

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Most of the K2 level participants were more a less at the same level, although in some cases, school one and school three were more active. Also, collaboration was stronger. But the creative play was the same throughout the whole sessions.

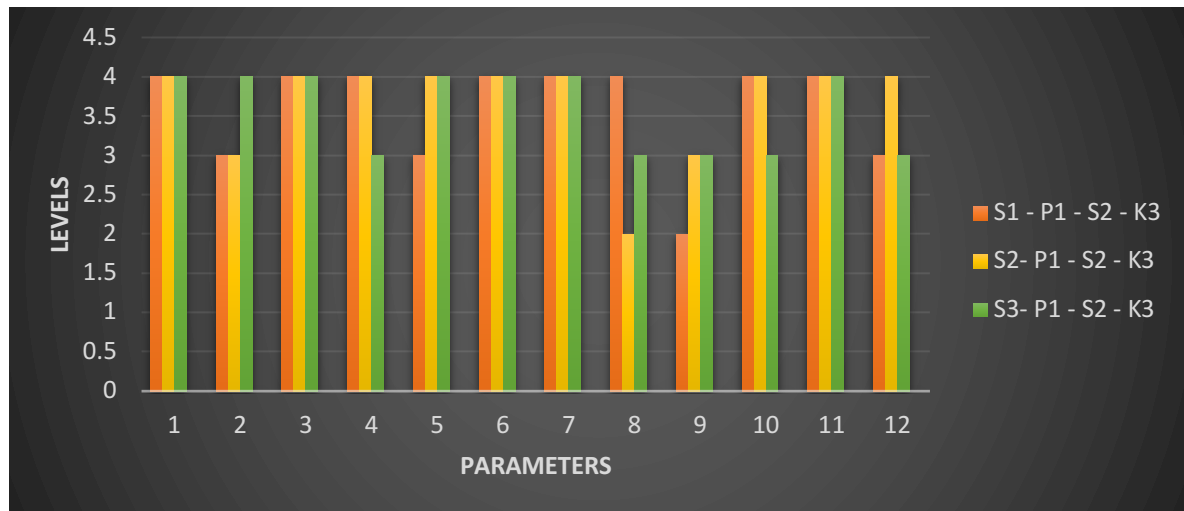


Figure 180 | 3 Schools - Part 1 - Session 2 - K3

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

It is evident that the K3 level for all the schools was quite similar; they were all stronger in session two. They were also more engaged then session one.

Part 2 – Session 1

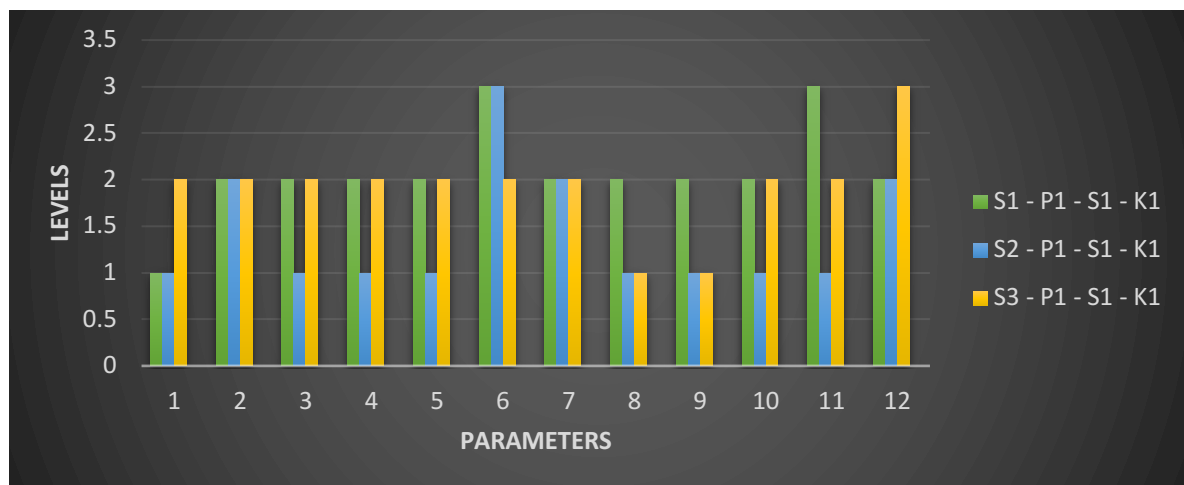


Figure 181 | 3 Schools - Part 2 - Session 1 - K1

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Most of the K1 level participants were more or less at the same level, although in the school two and three were stronger.

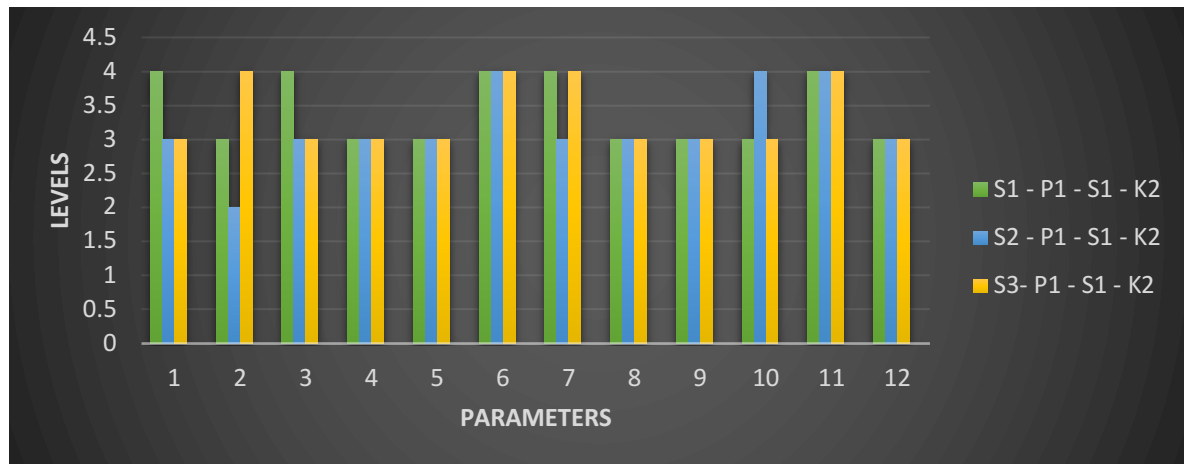


Figure 182 | 3 Schools - Part 2 - Session 1 – K2

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Most of the K2 level participants were more or less at the same level, only in some parameters school one and three were more active.

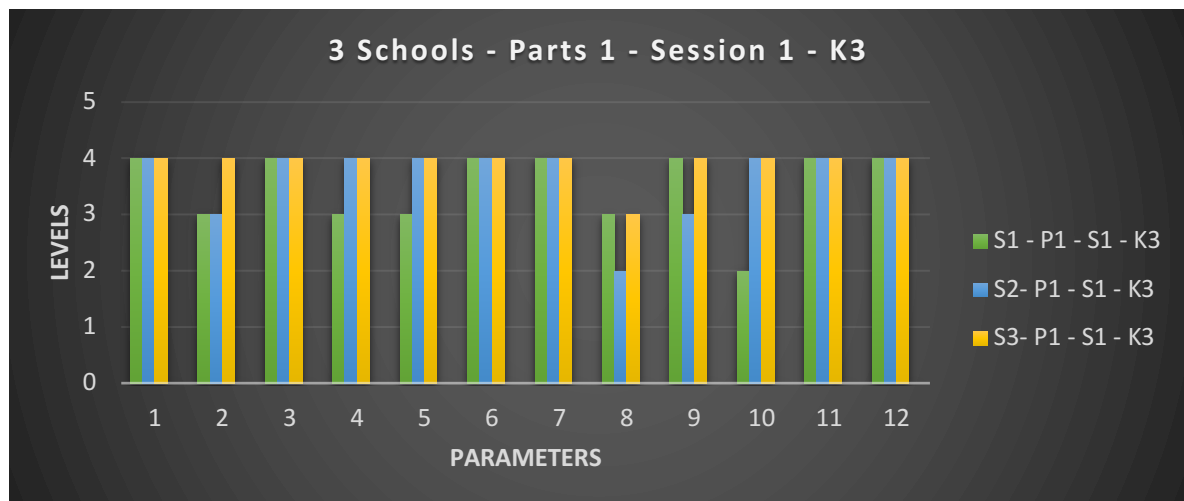


Figure 183 | 3 Schools - Part 2 - Session 1 – K3

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

It is evident that K3 of all the schools was more or less at the same level, and they loved to draw. We have given them much more paper in the free-play session for them to play.

Part 2 – Session 2

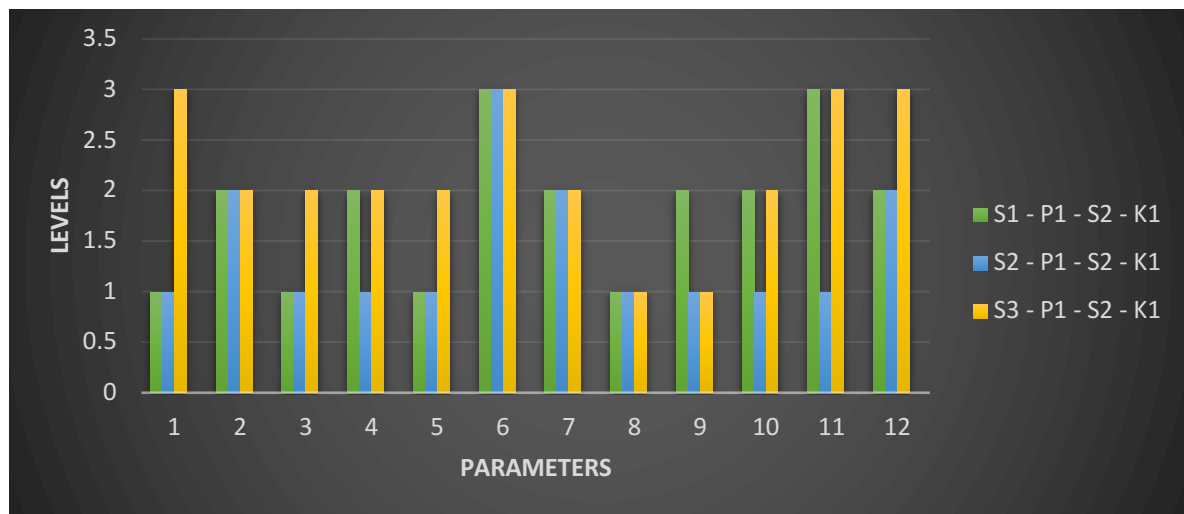


Figure 184 | 3 Schools - Part 2 - Session 2 – K1

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

In this session, the numbers differ a bit from one school to the other, but again, school one and school three were more active and open to this kind of collaborative game.

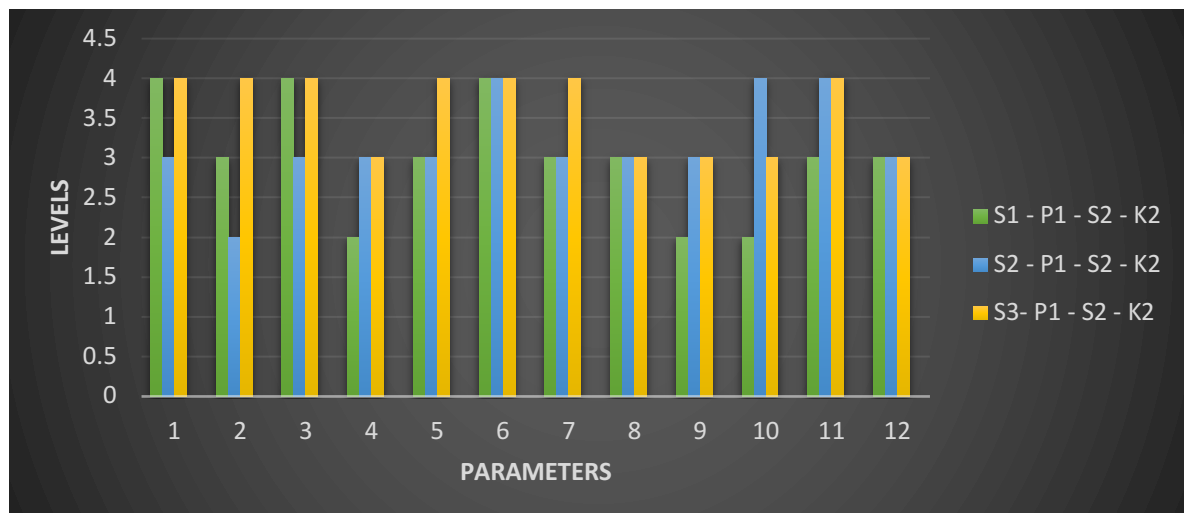


Figure 185 | 3 Schools - Part 2 - Session 2 – K2

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

Most of the K2 level participants from school one and two were more or less at the same level. Although in this session, collaboration was stronger in the second school. But the creative play was the same throughout the whole sessions.

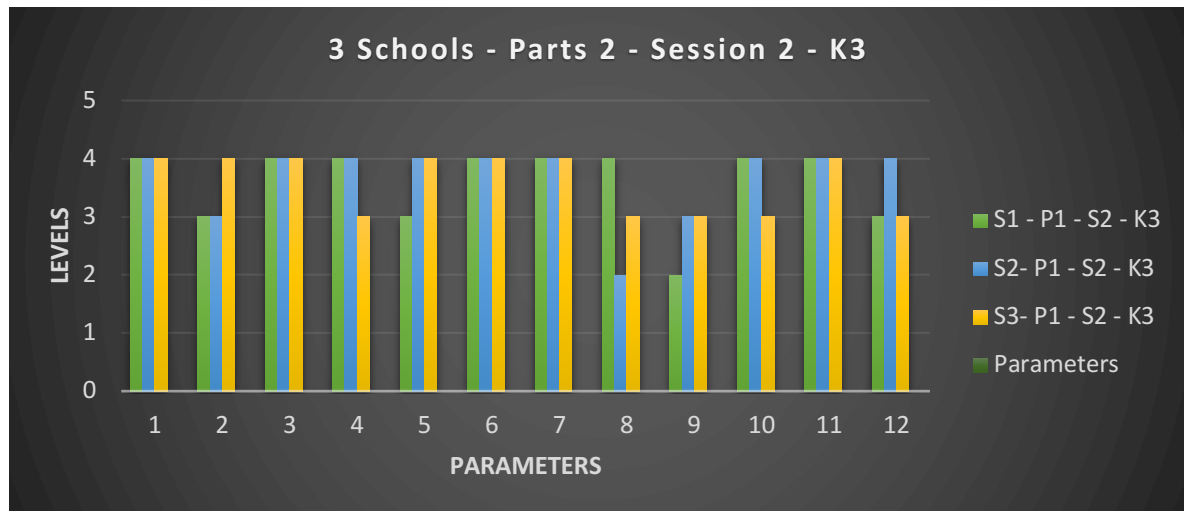


Figure 186 | 3 Schools - Part 2 - Session 2 – K3

Levels: 1 – Very Hard (it was difficult) | 2 – Hard | 3 - Medium | 4 – Easy (felt comfortable)

It is evident that the K3 level for all the schools was similar; they were stronger in session two.

5.3. Additional Considerations

All three schools used in our experimental studies did not use mobile platforms or digital games in the classroom environment, or any learning environment around the school before or while these experiments were being conducted. However, the schools had computer classrooms and digital whiteboards, but they did not use digital games as tools to teach students classwork or any other skills and abilities.

However, there are schools in Macau S.A.R. already using games, such as Minecraft, as part of their physics and math's class, as well as other digital games to assist in their classwork. Ricci School and Saint Paul's school are some of these schools. However, these schools usually only use games for higher levels of education, not Kindergarten.

All the personnel involved in the experimental studies had something to say. The feedback from the kindergarten principal, teachers, teacher's assistants and psychologists, were that, these types of games would make some of their classes more engaging and fun, since some children have difficulty focusing and having the opportunity to use these types of tangible/digital games in the future would be something worth thinking.

Teachers, at first, were quite inquisitive to know how they could use these games in the classroom to improve focus, thinking, and creativity. We had meetings with them before and after the experimental studies, and from our notes, we could notice that what they most needed was experience with these kinds/types of games. Some even requested that we would come more often and join their classes so they could be more up-to-date with these types of technologies to use in the classroom: not only books, videos, physical games, tactile games, and digital books.

Mostly they wanted to know why these digital games were so engaging. So, they joined our experimental studies, they entered the project with interest in educational games, but with limited technology and gaming literacy.

Observations, videos, and audio from the study clearly show that teachers had very little intervention while the experiments were going on, they were there to observe and make sure that the participants would not feel afraid or reluctant to reply to our questions. However, they still intervened when participants, especially from K1, had some difficulty in understanding the research student. This happened more in the second school than any other.

Teacher's interferences could turn disruptive behaviors into something positive, failures, and disturbances into learning moments. Creative behaviors and thinking were observed when participants felt at ease in the sessions, and the teacher's presence undoubtedly helped with this. During the studies, one teacher, from the second school experiment, was really surprised by the concentration the students displayed when playing.

One of the things we noticed was that if participants are not given the right instructions or if they misunderstood any of our instructions, their behaviors would be very different, and their final results quite different from what we would expect.

In the first part of the study, having in consideration that we only had one mobile tablet (iPad), we soon realized that we had to set up the experiment in a more collective/collaborative manner.

Consequently, what we did was we created more sets of seven pieces for all the three and then the six participants to play the Tangram game.

So, when they would be playing, they would not be waiting and getting frustrated that one was playing, and the others weren't. Our main idea was that both individual and collective data would be collected simultaneously. So, we set up the experiment in a way that all of them could play the game at the same time with and without the digital platform and still be engaged and think creatively.

5.4. Advantages and Constraints Encountered

5.4.1. Interaction Instruments

The OSMO Learning Platform is useful for teaching, and teachers have been communicating with the OSMO team, providing them with useful information on how they can be used in the classroom, so OSMO has responded by creating a classroom kit that has been used in various learning environments.

With the Tiggly Platform, the same is happening; schools are using it to enhance engagement, problem-solving, language teaching, mathematics, and colors, shapes recognition in classes, and there is an educational forum where teachers can also add their comments and points of view.

Although we had an excellent overall experience with both platforms, we encountered a few issues when doing these experiments, and in a classroom environment, this would be something that could disturb the class and the game experience, not only some annoyance from the children's side but from the teacher's side as well.

Table 27 | Platforms Strengths and Weaknesses

	Strengths	Weaknesses
Tangram Platform	The structure of the game and the storytelling and engagement of the whole puzzle discovery and achievements was something that the participants enjoyed. The platform has excellent graphics and icons that the participants enjoyed. They enjoyed the animations of the game and the environment of the game. The achievements section is also quite exciting, and the participants liked it. The game adventure section of the game is the one the participants most liked it. The visual and sound/music interaction was quite interesting. Colors are engaging and they really work well with this target audiences. More languages were implemented in the platform while we were doing the experimental studies as well as various little things related to the game play (the junior mode was also added). We only used English as the main language of the game. Quite complex puzzles, but for K3, they loved it. For K1 and K2, it was another story. This platform is also for an age group that is older, however, we had some K1 and K2 participants that could follow it quite well if they focused. The size of the tangibles was quite good for K1, K2, K3 participants since the pieces would fit nicely in their hands.	Hardware: Most of the time, the problems we encountered with the game was the readability of the pieces. Sometimes it took too much time for the children to get it correctly in place, which sometimes destroyed the game experience, it was quite time-consuming, tiring, and sometimes the participants would not stay engaged at all. They would give up and they would get bored and would prefer to play with the wood pieces on the table without using the game platform. Software: Lag and graphical glitches observed. Glitches became more frequent as the number of levels increased, preventing the game from being played. The instructions are not that good and not enough for all levels, K1, K2, K3. There are no voice instructions, so the sound and the music emitted from the platform was sometimes annoying, and the participants would not get what the platform was trying to say. Even the visuals were not enough for them to understand, the research student would have to help, so that means that in a game-based classroom, the teacher will always have to intervene. Some participants even asked to remove the sound of the game. Although we only used English, the game did not have audio cues using the English language, it was all sound-based, so it made no difference if it was English or any other language since most of the children could not read the things on the screen. Based on our observations, participants needed a version of the game that would have the pieces interact a bit more with the game. Example: the pieces could have names and then be identified by their names when the sound was emitted not only visual but also audio sound. There was also another factor that we believe made it difficult for the participants, even for K3, the beginning of the game. The instructions were limited at the beginning and assistance was always required from the research student.
Shapes Platform	The simplicity of this game platform has its benefits, such as easy playability for kids. Good graphics, simple, participants really enjoyed it. Only English was used, but additional languages were added later to the Shapes platform, which made quite a difference. The languages addition was also something that the participants enjoyed. The instructions, reactions and inputs were given in English in a pleasant and friendly tone. The size of the tangibles was quite good for K1, K2 and K3 participants since the pieces would fit nicely in their hands. The colors were basic and easy for the participants to use and understand. The stamp and the draw games provided the possibility of creating a storyline and their own characters, which was quite interesting for the participants, and it allowed them to be more creative.	However, sometimes simplicity can lead to other issues, there were a limited number of levels provided and there was an absence of storytelling in the Safari game, which we had to use another game in order to get this feature, so the participants in K2 and K3 felt bored, they wanted more. The safari game was not enough, participants also had to play the other two basic games that were provided by the platform, for the specific tangibles. Some of the games did not provide any other interactions or game play with the tangibles other than using them as stamps...Tangibles could have been used for so much more during the game play... Sometimes the graphics in the games provided by the platform did not match the tangible pieces. Consistency was not the strongest element. Although the voice instructor was quite exciting and engaging after a while, K3 participants would turn it a bit down.

While the participants played during session 1, in both parts of the experimental studies, the understanding of the physical objects and how they worked, as well as what they were used for and what they could do with them was quite strong. They had no difficulty understanding and interacting with these objects; however, sometimes the Tangram pieces were difficult to manipulate, especially the parallelogram. It was sometimes difficult for participants to flip it since they did not understand they could do it. They would rotate it instead of flipping it. They would get stuck. The research student would rarely assist in this matter, she would wait or/and ask the others to help if necessary, but most of the times, they would help each other without being asked. Collaboration in all levels was always present, in school one and school three. School two was not as open to it, but some would still help each other.



Figure 187 | The parallelogram

Both platforms provided a few interaction styles, but they all fitted based on our observations all the types of ages in our experimental study. However, the interaction style of the shapes platform was more acceptable by all the school's participants. They enjoyed quite a lot the sizes of the tangibles as well as the interaction with the mobile system. The biggest issue that we encountered was that the shapes tangibles were sometimes fragile. Although they had a robust outlook, the little black tips that would react with the mobile system would get damaged when the participants would play too much with them, this was not a problem for the Tangram wood pieces.

In terms of interaction, the Tangram platform provides two types of interaction: touch-screen based and the pieces that interact with the reflector. Occasionally, the reading of the pieces would be problematic. Since when the participants could not use the pieces on the table they would touch the screen and try to find what was the problem, but because they are no voice instructions this was difficult for them.



Figure 188 | Reflector's Interaction with the physical pieces.

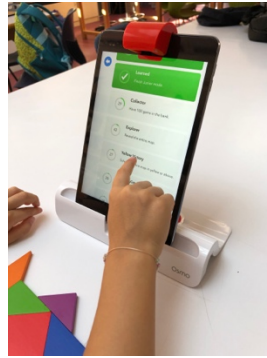


Figure 189 | Touch Screen Interaction

In terms of interaction the Shapes platform also provides two types of interaction: the player can choose to use the touch-screen (finger touch), by using their hands or they can use the tangibles. For the participants to use the Tangibles, they would have to first unlock each of the shapes by placing them on the mobile screen.



Figure 190 | Print screen of the game (only for analysis purpose)

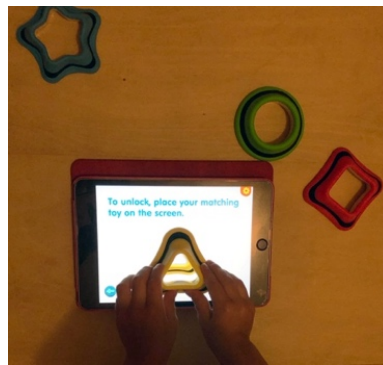


Figure 191 | Photo of the game to unlock the Tangibles.

Two modes of interaction – Tangibles Interaction or Touch-Screen interaction

5.4.2. Instructions

Tangram Game - The game instructions had to be given by the research student, since the platform instructions were not easy to follow, especially for the three and four year olds, even the five and six year olds had some issues. The game itself is quite suitable for children from three to six years of age, but most of the time, to access the game or to go from one level to the other, assistance would be needed. The music and sound cues were not enough to understand the gameplay, and only the visual instructions were helpful. A

voice instruction would have helped substantially (which was what the research student was doing).

Shapes Game – The game instructions did not need to be continuously given by the research student, just when the participant needed some help. The voice instructions were proper, but after a while, they got a bit annoying, and the participants would lower the sound.

The same happened with the sound from the Tangram game.

Participants of these ages need more instructions to be able to move forward, and some can do it on their own while others need help. Here is when instructors/teachers can come in and help them achieve their goals. One of the good things about games is that, once the player knows how to play and is not afraid to go forward, instructions (voice instructions) are only there to guide them if they forget something along the way, although teachers or instructors can also do this. Lack of instructions or incorrect instructions may sometimes create a bit of annoyance amongst younger and impatient four or five year olds, and they might tire of the game and stop playing. Engagement is a big thing, and instructions also help with this.

5.4.3. Tangibles and Manipulatives

In session one, we introduced the tangibles and the manipulatives that assisted in session two on purpose. Since our participants are quite young in the first part of our experimental studies, we always introduce a physical manipulation session only, so that they get used to the second session that connects the tangibles and manipulatives to the digital game. Physical and Digital worlds get together.

In both activities, the manipulatives, objects, and tangibles used were already familiar to the participants.

5.4.4. Interface Usage

Part 1 of the Experimental Study

Session 1 – The physical interface used was an A4 paper with a printed puzzle, this is somewhat similar to what participants had already used or seen. The physical tangram pieces were also something they had used before. So, it was not problematic for them to understand the task on hand.

Session 2 – The digital interface was not totally new, some of them already knew how to use the tablet (with their fingers). However, almost all of them have never played the game, so it was quite exciting and engaging, although we had some difficulties, not all students were able to use it because they don't really know how to read (here the research student frequently had to help them).

Session 3 – In this session, as mentioned above in 5.2.1, 5.2.2 and 5.2.3. of this thesis – analysis of the parameters, all participants were able to use both interfaces with no issues.

Part 2 of the Experimental Study

Session 1 – The physical interface used was A4 papers with crayons and the shapes tangibles, again this is somewhat similar to what participants had already used or seen. Tangible pieces were also something they had used before, so it was not problematic for them to understand the task in hand.

Session 2 – The digital interface was not new, some of them already knew how to use the tablet (with their fingers). However, most of them have never played the game, so it was quite exciting and engaging, and although we had some difficulties, all students were able to use it.

Session 3 – In this session, as mentioned above in 5.2.1, 5.2.2 and 5.2.3. of this thesis – analysis of the parameters, all participants were able to use both interfaces without issues.

5.5. Short Survey – Quantitative Data

This survey only shows how many participants have played the games, as well as what they liked most in these sessions. We needed to know their quantifiable input as well, to have some basis for the acceptance of our framework in the classroom.

The following survey data is organized by the Kindergarten level and not by the school. Please review.

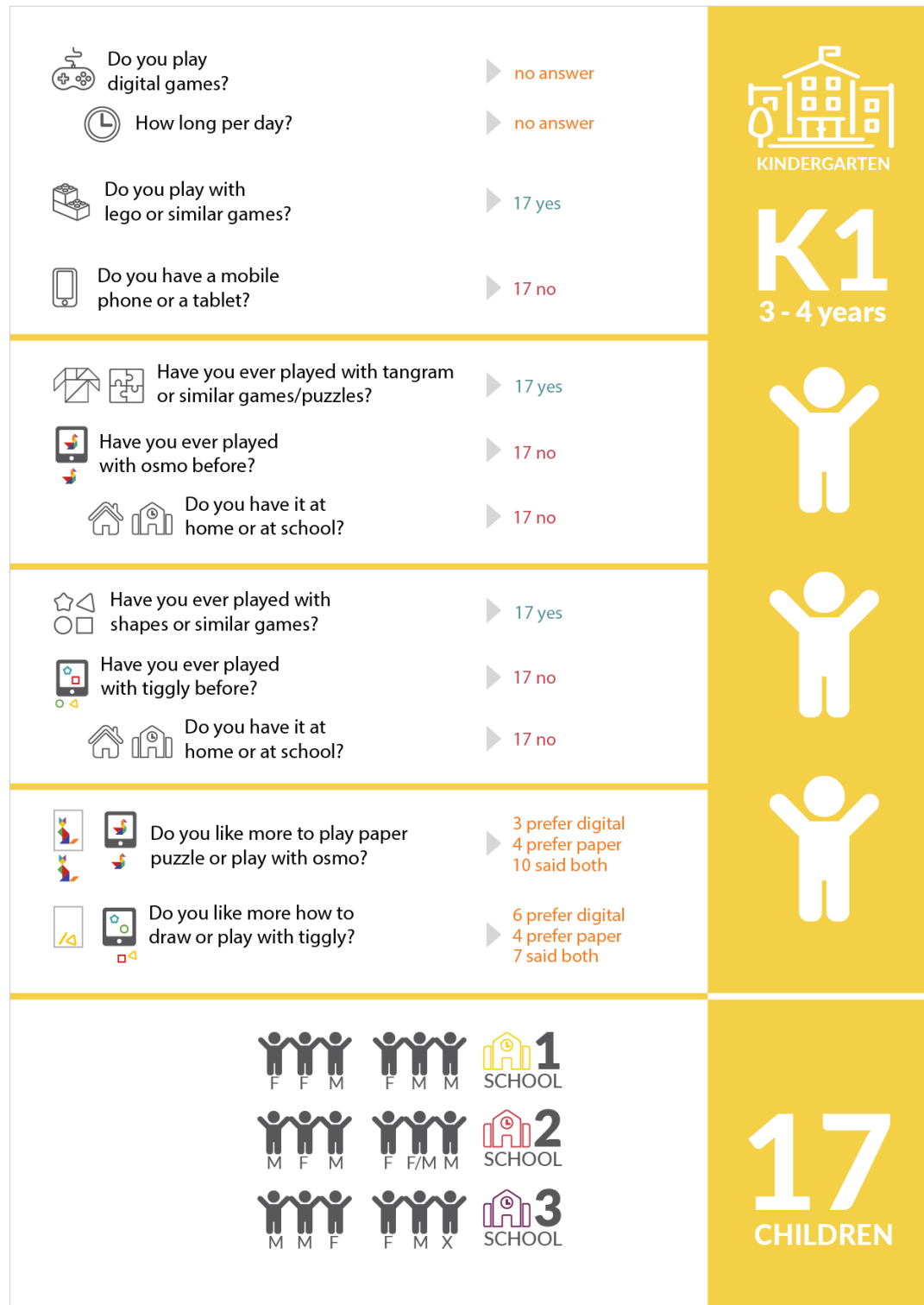


Figure 192 | Survey K1 | 3 - 4 years | 3 schools

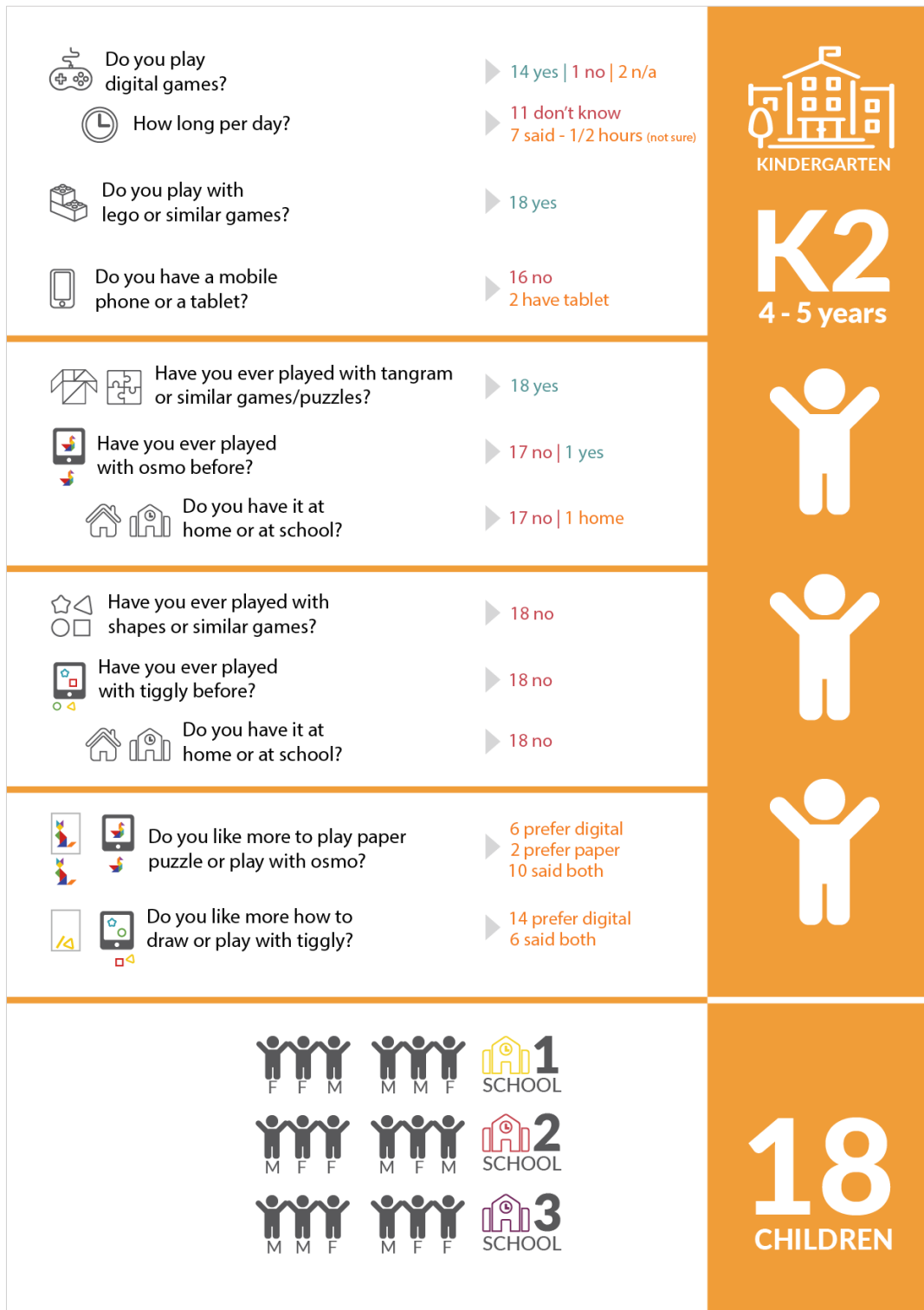


Figure 193 | Survey K2 | 4 - 5 years | 3 schools

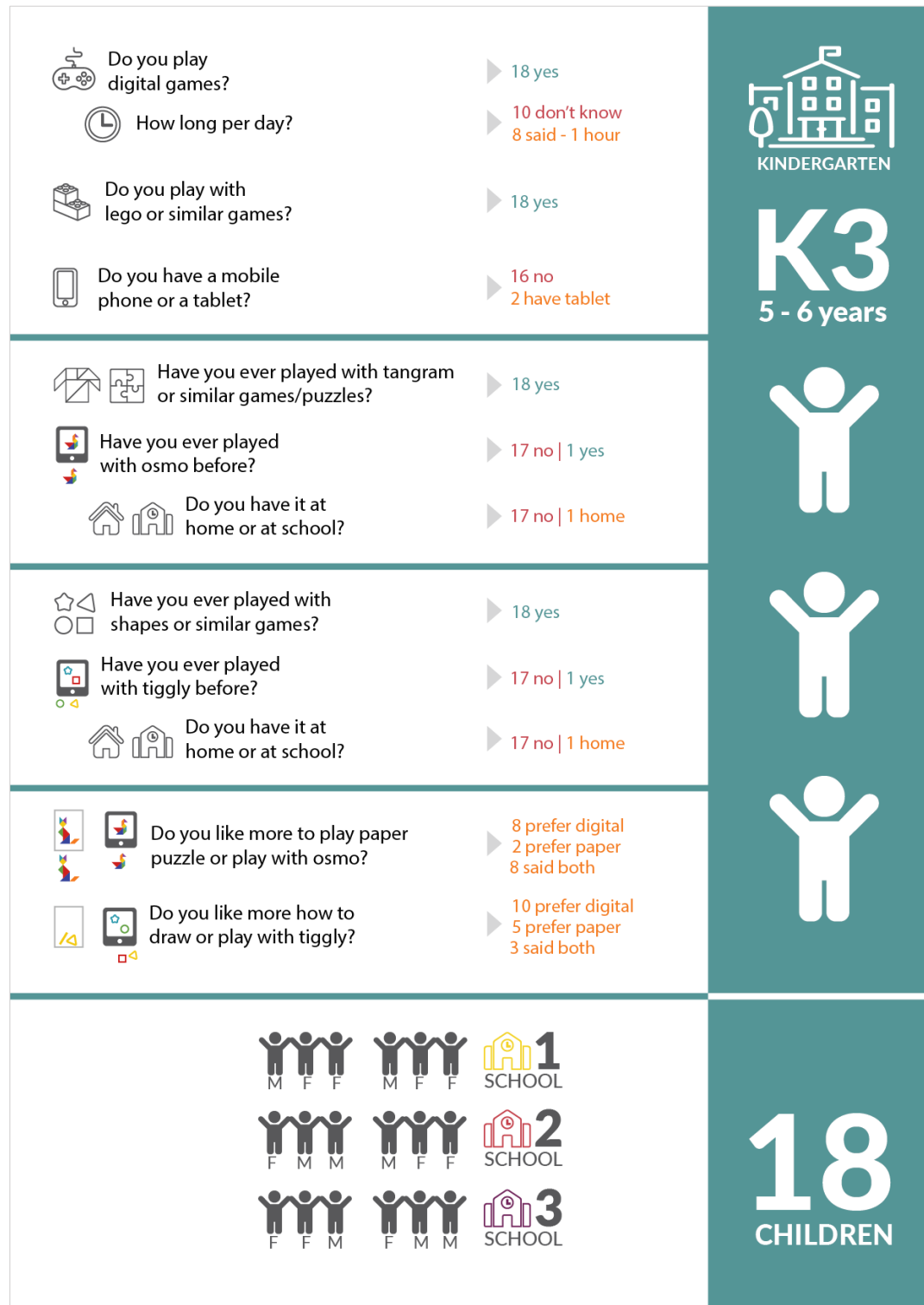


Figure 194 | Survey K3 | 5 - 6 years | 3 schools

5.6. Conceptual Framework | Multimodal Interactive Game Design Models for Fostering Creative Behaviors -- Proposal for Macau Education.

5.6.1. Structure, Explanations and Recommendations

After the analysis and conclusion of the research studies, we believe that we have found a strategic plan for the implementation of digital and tangible game sessions in Macau S.A.R., adapting to each participating school's daily activities, without interfering with their activities time.

In this section, we will provide a framework for snack multimodal game-design sessions in a collaborative and creative learning environment.

Having in consideration that we created six multimodal interactive experiences for the classroom, using digital and tangible games, we would like to propose a framework model based on our experimental studies and inspired by CATLM - A cognitive-affective model of learning with media, by Moreno 2005a, the Vark model, having in consideration the MDA Framework (Hunicke et al., n.d.), flow in games (Csikszentmihalyi, 1988) and systematic creativity (Ackermann, Gauntlett, & Wolbers, 2009).

One of the main challenges in multimodal interactive environments is that these environments are quite demanding because they require a lot from the cognitive system of each child/participant, they can have a cognitive overload, as mentioned in chapter 3 of this thesis (Moreno & Mayer, 2007).

Taking all of this into consideration, we created a more flexible environment where children can have more fun and less tension while still giving space for flexible and creative thinking. We define our framework as – Snack Sessions. These snack sessions are based on a collaborative and creative environment.

Bearing in mind Sensory Memory, Working Memory, Long-Term Memory (CATLM), we created various sessions so that the participants from our study could feel comfortable with what they were experiencing, which meant showing them and letting them experience a more familiar environment, which was achieved.

Snack Sessions Framework - VADT | Visual – Audio - Digital – Tangible

The V.A.D.T. Snack Sessions last forty-five minutes overall, but they are sub-divided into sessions of 15 minutes – although the first snack sessions took a bit longer.

In the first session, we used only physical and printed/visual materials, and we familiarized the participants with a short session in recognizable settings, i.e., a game that they have played before or a task that is similar to the games that will be used in the second session. The activity has to provide input into the next session.

Understanding that participants from three to six years of age have different difficulties and demands, we tried not to overcomplicate. Puzzle games are recommended since they have a significant impact on every child's cognitive development, problem-solving, motor development, hand and eye coordination, collaboration, and self-achievement. We tested with geometrical shapes, and it also presented benefits, although the digital game has to have more engaging plots and storylines to captivate the participant's engagement.

The use of puzzle games that consider the hand size of children from three to six years of age is optional. We believe that a tangible piece no bigger than 7 cm with 2.5/3 cm of thickness is enough. Bigger than this, it becomes too cumbersome, any less, and it becomes too small for this kind of session in the classroom. The tangibles and manipulatives have to have a good grip, and participants have to be able to sense them in order to understand how they work before moving to the digital platform game.

In the second session, the participants should have already achieved the necessary familiarization, since they have paid the required attention and perceived well the information given by the instructor.

In the third session, we allow participants to play freely, taking into consideration both sessions, session one, and session two.

Here are the characteristics of our V.A.D.T. Snack Sessions Framework:

Our game-based framework is based on flexible design patterns that attain essential visual and audio elements, have been developed to allow children to play and learn through engaging and fun environments triggering creative behaviors and their social influences.

Table 28 | V.A.D.T. Snack Sessions Framework

Factors	Session 1	Session 2	Session 3
LANGUAGE	Any language can be used, although it has to match each school's environment and curriculum languages. Use the language that is most comfortable for the participants and find games that provide no language barriers – digital or physical games.		
TYPE OF SESSION	Visual & Print Session (Physical World)	Digital & Tangible Session (Digital and Physical Worlds)	Mix Sessions (1 & 2) – Free Play
TIME TO CONDUCT SESSION	Instructions (make it short) + 15 minutes	Instructions (make it short) + 15 minutes	Instructions (make it short) + 15 minutes/30 minutes of class activity.
INSTRUCTIONS & GUIDANCE	Instructions should be given at the beginning, even if you have done this before. After the instructions, tell them to do whatever they want with the puzzle pieces, the geometric pieces or the guidance paper and crayons. (Free-Play)	Guidance throughout the session should be given even if they know how to play. – note here that a game that provides music/audio guidance is more welcoming for each participant than without it. Instructions should be given at the beginning, even if you have done this before.	Free-Play No instructions. Just do whatever they want following that they have to play the games.
GOALS	Goals of the session and each puzzle. 3 to 5 puzzles within 15 minutes depending on their complexity. What are the puzzles about?	Goals of the session and use of tangibles and digital platform. How many puzzles or shapes should the participant complete. 3 to 5 puzzles are possible to be completed	Goals of the session and use of tangibles and digital platform. How many puzzles or shapes should the participant complete. This session to be done in a bigger group and this requires collaboration.
COUNTDOWN TIMER	Timing monitor for each puzzle. Countdown timer for each puzzle.	Timings to monitor each puzzle and/or level. Song or music that has a countdown timer to finish.	Timings to monitor each puzzle and/or level. Song or music that has a countdown timer to finish. Teacher/Instructor here can give instructions and guidelines (time is almost done)
MANIPULATION	Pictures (visual guides) + Manipulatives (physical objects) that have color and are passive (no sound).	Digital Aid/Digital Interaction + Tangible Objects (digital world + physical world)	Digital Aid/Digital Interaction + Tangible Objects (digital world + physical world)

PHYSICAL AND DIGITAL INTERACTIONS	Interaction between printed/drawn images and physical objects. Pictures/Outlines/Printed Images/Colors Simple words/Manipulatives that Mimic the second session or the Tangible Objects.	Interaction between digital platform/system and tangible objects. Graphical User Interfaces – Colors, drawings, silhouettes, buttons, graphics, words... Sound/Music Tangible objects	Interaction between printed/drawn images and physical objects. + Interaction between digital platform/system and tangible objects.
PLAY	Systematic Play - Creativity Thinking is always offered in this session.	Systematic Play - Creativity Thinking is always offered in this session.	Free-Play
COLLABORATION ATTITUDE	Collaboration will be suggested from the instructor.	Collaboration will be given, at times, to each other without the assistance of the instructor.	Collaborative play given to each other without guidance.
CREATIVE THINKING ATTITUDE	Give time for out-of-the-box thinking, let the participant use the same materials used in this session to create with them something different based on the theme of the game. Let them play creatively and freely in the last part of the session. There is always time for this.	Give time for out-of-the-box thinking, let the participant use the same materials used in this session to create with them something different based on the theme of the game or based on the respective gameplay of the games/activities.	Give time for out-of-the-box thinking, let the participant use the same materials used in both sessions to create with them something different based on the theme of the game or based on the respective gameplay of the games/activities.
STORYLINE CONSTRUCTION AND UNDERSTANDING	Games have to provide a way of producing storylines.	Games have to provide a plot (storyline) or free storyline mode.	Free storyline mode should be provided.
GRATIFICATION	Gratification – Always provide it. Yeah! Well done!	Gratification – the digital tangible game should provide small gratifications.	Gratification Always provide it. Yeah! Well done! + The digital tangible game should provide small gratifications.
ACHIEVEMENTS	Show the Participants their Achievements – use stickers or anything related to the digital/tangible game that is coming in the next session.	Show the Participants their Achievements – use stickers or show the graphs of the games to show how they are doing.	Show the Participants their Achievements – use stickers or show the graphs of the games to show how they are doing.
IMPROVEMENT	Games used in this first session have to allow for improvements.	Games used in this first session have to allow for improvements from last session, as well as the current session.	Desire to improve their performance from last sessions.

Note: Usually class activities duration in Macau S.A.R. are around 40 to 45 minutes each.

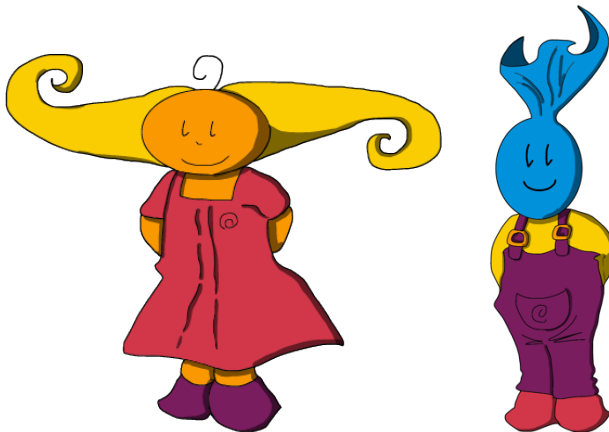
To implement the framework above, it is essential that the parameters mentioned in 5.2. in the data analysis section are used to evaluate the activity.

Collaboration and Creative Thinking is accomplished if sessions are well organized and if games follow a storyline, puzzle structure, or a plot. Also, puzzle games have a great way of opening participants' way of thinking and providing interactions that are quite open and out-of-the-box (Puzzles for children, s.d.).

Puzzle games also allow for failure, and the option to try again, and again, which makes it challenging and gratifying in the end. Creative play is also enhanced by the social collaboration of each participant with one another, so always try to have at least a group of two students per digital device. Do not use one digital device for each participant.

Although with three participants per device, it is more challenging when they are in a classroom environment, as it requires more coordination from the instructor. Collaboration and out-of-the-box thinking are essential, so they can all play with each other since collaboration should be enhanced in children from three to six years of age.

The use of Digital or Tangible instructors, specifically for K1, K2, and K3 levels, is recommended. The leading instructors should be humanoid/like characters that are with the player all the way, throughout the gameplay, and as needed by the participants.



Above are our versions of the digital game instructors and/or tangibles for our game design, Miss O and Mister I. We believe that if they are added to each session, they can have a significant impact on the session's functioning and creative enhancement, even more so if the puzzles and the tangible game have a storyline approach to it. (Osmo has implemented something similar to this in another game (<https://www.playosmo.com/en->

gb/monster). Various other games have similar instructors in games. However, this could not be implemented digitally only, and we believe that having the Tangible Object would be a plus, and it could be used in the first session of the framework as an introductory key element to the other sessions.

Another recommendation is regarding time spent on digital devices at very young ages, and we believe that these sessions can be implemented once or twice a week. However, to start this implementation slowly, maybe twice a month, in a time slot of 45 minutes dispersed throughout the week and part of the curriculum in Macau S.A.R.

We do not believe or recommend, based on our experiments, that this can be done with any game or any platform. Games and platforms need to be studied and assessed before being implemented in this framework. That is why we tested two different digital platforms, to know what the benefits were, of each, in a direct environment where participants would be eventually using it. Nevertheless, for this to happen, we believe that teachers or instructors around Macau S.A.R. should have the knowledge of which games and digital platforms they should use. For that, we believe that research and more experimental studies of this kind should be conducted in order to provide more direct guidelines. The teacher needs to instruct the participants in the subject matter being taught throughout the sessions, as well as the preliminary way of playing the game.

Nevertheless, they will also need to step into an authoritative role whenever necessary to keep participants focused. This happened throughout our experiments.

Note: While we did not give any gratification to the students the first time we did the experiments (part 1), we came back to work with them with a new game in mind. Moreover, the participants already knew what was expected from them, so the sessions were even more creative, fun, and collaborative.

During our experimental studies, the participants were quite open to these new activities, although they have not been part of studies like these before, we believe that it was a success.

Though some participants had some minor difficulties, we believe that our framework can be implemented in schools around Macau S.A.R.

5.7. Conclusion

This chapter is divided into the following sections: Data Description (by school, groups, and sessions); Data Results and Analysis (based on school, kindergarten levels, sessions, and experimental study parts); Add-on Explanations; Benefits and Constraints; Short Survey; Conceptual Framework Explanations and Conclusions.

Also, we described what happened during our experimental studies, as well as analyzed all the videos based on twelve parameters that we created during our research.

These analyses are based on our experience and knowledge of what happened during our experience within these studies, but this does not guarantee that another researcher will not analyze it differently. We choose this way of analyzing our studies, taking into consideration all the set parameters based on game design practices as well as game experiences.

CHAPTER VI

CONCLUSIONS

& FUTURE

DIRECTIONS

CHAPTER VI

6. Conclusions & Future Directions

Tangible and Digital Technologies have transformed the way children learn and interact in schools. Digital games are at children's fingertips, and we have to take advantage of this technology and use it in learning environments. Although this is being applied all around the world, Macau S.A.R. is still in its beginning regarding this matter, and there is much room for improvement and growth.

To answer our main research question, we focused on various approaches and research fields to understand how we could move forward with our approaches to implement multimodal digital games in learning environments.

How can multimodal digital games be used in children's learning environments, specifically for fostering creative behaviors through user-centered design approaches?

This dissertation addresses a particular aspect of the field of digital games, which focuses on the usage of tangible/digital games in learning environments, with an emphasis on creative behaviors and the creative class. The research carried out over the last five years stems from a basic understanding of Human-Computer Interaction, User-Centered Design, Multimodal Interactive Environments, and Tangible/Digital games.

Considering that technology is paramount in schools, specifically in classrooms, we still need to interact with physical objects to learn how to use them. The pen, for example, is a tool for hand-writing, so even a digital pen needs to be handheld. One of the most significant problems of the implementation of new technologies in the classroom has to do with how kindergarten children handle it.

Seeing that our studies involve children of a very young age, we had in consideration that they learn firstly by manipulating objects with their hands, stimulating motor responses. These motor responses are steered by combining the digital and physical worlds, (Berti & Paternò, 2005), creating opportunities for learners to expand new/old concepts and skills.

Our focus consists of games that have a double component, a digital, and a physical one. These games are for players/children between the ages of three and six (the creative age) and their development needs, and these two components are necessary for this age group.

Young children are exposed daily to these new kinds of interactions and physical flexibilities when they are accessible to game-based learning environments allowing them to develop their character and ideas (de Abreu & Barbosa, 2017).

Research studies involving tangible interactions, digital games, and children usually focus on comparing how traditional media learning methodologies and tangibles might support learning (A. N. Antle, Droumeva, & Ha, 2009). However, based on our studies, we trust that a combined approach might be a better solution.

Based on other research studies (Horn, Crouser, & Bers, 2012) we worked closely with specific schools to learn how multimodal games with physical and digital components (audio, visual, and tangible) work as creative mediators and its impact between the teacher and the learner.

A mixed reality (multimodal), is a term used to refer to the merging of physical and digital representation outputs (O'Malley et al., 2004). TUI's, tangible technologies are part of a wide range of ubiquitous computing (environments) that are rooted in our daily lives. Children grow up with these technologies around them, and teachers and educators have to learn how to speak their language. We believe that through multimodal games, communication and language barriers become far-reaching since one of the most significant problems that education is currently facing is that teachers and educators might not have the knowledge needed to teach with technology.

Traditional educational methods give very little room for students to develop their creativity and out-of-the-box thinking; this has been seen all over the world. However, we do not believe that only digital games alone can be implemented in classrooms, as mentioned above, and throughout this thesis.

Today's learners' multi-task in ways that some educators are not open to, graphics and icons are the first things that they will look for rather than text. They improve their skills

by seeking instant gratification, understanding, and response, mirroring their experience in digital games (Prensky, 2001) making no extra effort.

6.1. Implementation of a Proof-of-Concept Framework

In order to examine the significance of multimodal interactive environments with multimodal digital games with tangible/digital technologies for creative behaviors in a learning environment, fifty-three children aged between three and six, in three different kindergarten levels, of three different schools, were observed in a similar environment. They sat in a *classroom* where they played with tangible/digital technologies and followed a framework that combined a traditional/physical approach and a digital/physical approach.

Our goal was to develop a functional proof-of-concept framework and test it in a real school-based environment, using theoretical analysis with tangible user interfaces (TUIs).

We first focused on how to set up this framework, with specific guidelines that focus on multimodal interactive games for schools that want to increase and empower creativity levels in the classroom through a snack session activity method.

We also focused on a practical aspect of how interaction and creativity are interconnected with students' behaviors in a classroom setting so that students can learn to have more creative behaviors, which is something they would take further outside classes.

Various other elements were explored, such as media, graphics, art, literature, creative methods, audio and visual modules, user interface design, and students'/players' interactions.

6.2. Additional Exploratory Questions we had in our Studies;

These are just short conclusions related to what we have studied during this research.

- How are game-design modules in games with learning content, relevant to education?

It is paramount that games provide the following: clear visual symbols, specific text, clean interfaces, necessary language, and clear audio cues with no chance for misunderstandings. Emphasis on background culture with learning content relevant for children's daily activities, inside and outside of school, are essential for education and should be taken into consideration when applied in these environments.

Games with learning content must not forget that children learn in different ways and that guidance, collaboration, gratification, achievements, and goals, have to be provided within the game and that creativity is instigated in the way they play. Time for out-of-the-box thinking and free play has to be given in these types of games in order for children to develop creative behaviors in a learning environment.

- How can audio, visual, digital and tangible features in games be incorporated in education and intensify student/creativity?

As mentioned before, the main features must follow a clear, clean, and instructive guideline. The guidelines, discussed in chapter 3, must center on relevant audio/visual elements that children have had prior contact. This applies to tangibles and manipulatives as well. In order for digital games with learning content to be implemented in learning environments, teachers and instructors must be aware of how they work in both an individualistic and collaborative setting. Before implementing games with physical and digital components, teachers and instructors must rely on game-based models and test the platforms before class activities.

- How can multimodal digital games change the way educators instill creative behaviors in schools?

Educators must be familiar with the variety of games that are in the market and that have good learning content for the classroom, they must also comprehend how they can use them in a class, specifically to instill creative behaviors. Educators have to first test the

games, to some extent, to identify the outcomes they would like to achieve and also to see if the game is suitable for teaching.

Multimodal digital games provide more flexibility in the way they are implemented in the classroom, as well as the gameplay of the game. Games that provide various components, tangible, digital, audio, and visual interactivities provide better outcomes with children this age, that is what we have seen during our experiments. Nevertheless, the games have to be carefully chosen and tested before implemented, using our framework.

- What are the characteristics of multimodal interactive and non-interactive digital games that are relevant to the creative process of a child?

Multimodal digital games provide several means of communicating and interacting. Each child interacts differently and experiences it in diverse ways having in consideration that each of their senses, experiences the games on hand differently. A Multimodal experience can be interactive when using real-world objects, simulations, and skills in collaboration with other children around them, they not only interact with others but with the game in hand as well. It can also be non-interactive when providing benefits coupled with images, sounds, listening, and reading individually or in a group. Upon reflecting on our pilot experiment, we believe that multimodal games and environments are crucial for a child's creative process, it allows them to think differently and find solutions and ideas that have value as well as experience the world in a different, fun and engaging way.

6.3. Future Work

This was the first pilot experimental study organized in the Macau S.A.R., where the studies were completed with a small group of children in various different levels of education and three different schools using our proof-of-concept framework.

Our main objective is to extend these studies to at least two hundred Asian schools, and we would reach more schools in Macau S.A.R., as well as other cities such as Hong Kong, Taiwan, Singapore, where we foresee implementing challenges but yielding different and promising results and exciting interactions. We believe that with direction and explanation, as well as the necessary modifications to the framework, it is quite doable.

At the moment, the deployment of this framework in Macau S.A.R. is our main focus, and for that, we will communicate with more schools and explain our framework and findings, how these small snack sessions can be implemented as part of a school's curriculum and how multimodal digital games can be tested and experimented before their implementation in such activities.

Further research will be done into other multimodal digital games that could be implemented in schools, and these games will be tested first, as before, with small groups of learners before applying it in schools with more than twenty students per class.

We will continue to take into consideration that not all games are suitable for this type of framework, as well as that not all are appropriate for learning environments.

The final results of this dissertation have not been published, as of yet, in journals, but we will focus on making sure that our framework, with all the necessary explanations and final results, gets published, having been only published in peer-reviewed conferences.

Attention will be paid on creating a multimodal digital game prototype where we will implement specific characteristics of the games that were investigated, containing all the pros and cons found during our experimental study.

To finalize, we will be integrating into our framework the possibility of children creating their part of the game, just like they had done before when we gave them the opportunity

to free-play. We want to implement this by taking into consideration that in the free-play sessions, the children had more time for these types of accomplishments.

The application of these new features in our framework will help us strengthen our theory that flexible types of multimodal interactive environments will undoubtedly increase creative behaviors in a school setting and also upsurge our knowledge in this field of research.

6.4. Personal Conclusion

This is a new field, in Macau S.A.R., with substantial opportunity to help increase knowledge and studies in the area of multimodal digital games for educational environments. As a researcher, lecturer and designer, we will continue trying to implement better and more open-ended studies with the intention to supply teachers, instructors and learners to work with our current and future frameworks.

At the end, we experienced an exceptional challenging project, with long hours collecting data and compiling and reviewing documentation, meeting new people, interacting with children, witnessing out-of-the-box moments, that imbued new emotions, knowledge and an altered perspective in us, they will be cherished and remembered.

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APPENDIXES

APPENDIX A:

Permission for Participation of Macau S.A.R. schools in our research project – This document was also sent to each specific school with the name of the director of the school as well as the explanations of the project.



Pedido de autorização para fazer estudos em escolas públicas de Macau que fazem parte do Projecto de Investigação, "Design de Jogos para a Criatividade na Educação: Audio-Visuais e Modelos Tangíveis de Interação do Utilizador" Doutoramento em Ciências e Tecnologia das Artes – Arte Interactiva

Macau a 24 de Março de 2017

Cara Directora Dra. Leong Lai,

Vimos por este meio solicitar a sua autorização para poder incluir as escolas públicas num projecto de investigação que terá lugar a partir do final de Março até ao final de Junho de 2017 em diversas escolas do território.

Este projecto de investigação visa a que os participantes façam parte de um estudo onde iremos analisar como os mesmos jogam e interagem com jogos digitais e tangíveis com componentes educativas. Isto será conseguido através de filmagens que serão feitas durante as diversas sessões a fim de obter dados tangíveis para serem analisados mais tarde.

Através deste estudo tentaremos compreender como os alunos, individualmente e em grupo, utilizam a criatividade, a jogabilidade e a colaboração para resolver cada jogo. Esperamos obter através da observação e da explicação dos jogos aos alunos, várias soluções em cada uma das sessões, como por exemplo, como é que a criatividade ao longo do tempo do estudo se modifica, e como, com o treino desta ela se transforma. Para finalizar, observaremos também como é que o mundo físico e o digital se auxiliam na aprendizagem criativa dos participantes.

Esperamos obter resultados positivos deste estudo, que sejam um contributo científico válido para o desenvolvimento e o futuro da aprendizagem nas Escolas de Macau.

Todas as filmagens e sons capturados serão dados à Instituição de ensino e não serão divulgados ou partilhados em nenhuma plataforma social ou televisiva. No entanto, este estudo poderá ser usado para fins de apresentação sob a forma de fotos e gráficos de dados em documentos de pesquisa. Caso as fotos sejam usadas, garantimos que elas não terão o reconhecimento facial das crianças.

Toda a documentação relacionada com este pedido encontra-se em anexo tal como a proposta de tese.

Muito obrigado,
Melhores cumprimentos.

Approvado por

Álvaro Barbosa
Director da Faculdade de Indústrias Criativas | USJ
Orientador de Doutoramento | UCP

Approvado por

Carlos Sena Caires
Cordenador do Departamento de Design da Faculdade de Indústrias Criativas | USJ
Co-Orientador de Doutoramento | UCP

Assinatura de

Filipa C. A. Martins de Abreu
Aluna de Doutoramento
Professora | USJ

Para mais informações por favor contacte a doutoranda Filipa Martins at filipa.martins@usj.edu.mo ou então telefone para 66583685.



Permission for participation in the Research Project,

"Game Design for Creativity in Education: Audio-visual and Tangible User Interaction Models"
Doctoral in Science and Technology of the Arts - *Interactive Art*

24th of March 2017, Macau

Dear Director Dr. Leong Lai,

We are writing this letter to request your permission to include public schools in a research project that will take place at the end of March until the end of June 2017 spanning various schools in the territory.

This research project involves participants, to take part, in a research study where we will analyse how they play and interact with digital and tangible games with educational components. This will be achieved by filming them during each session in order to record data and analyse it afterwards.

The study revolves around understanding how a child, individually or in group, will use their creativity, playfulness and collaboration to resolve the game. We hope to observe a myriad of solutions in each session, how creativity changes through time and training and ultimately how the physical and the digital worlds assist in the creative learning of a child.

We hope to obtain positive results from this study, which will be a valid scientific contribution to the development and future of learning in Macau Schools.

All the films and sounds captured will be given to the school and will not be publicized or shared in any social platform or television. However this study maybe used for presentation purposes in the form of photos and data graphs in research papers part of the research project mentioned above. If photos are used they will not show facial recognition of the child.

All the documentation related with this request is annexed for your reference including the thesis proposal.

Thank you,
Best Regards,

Approved by

Álvaro Barbosa
Dean at the Faculty of Creative Industries
| USJ - PhD Supervisor | UCP
http://www.usj.edu.mo/en/faculty_directory/alvaro-barbosa

Approved by

Carlos Sena Caires
Head of the Design Department at the
Faculty of Creative Industries | USJ - PhD Co-
Supervisor | UCP
http://www.usj.edu.mo/en/faculty_directory/carlos-sena-caires

Signed by

Filipa C. A. Martins de Abreu
PhD Student | UCP
Senior Lecturer | USJ
http://www.usj.edu.mo/en/faculty_directory/filipa-martins

For more information please contact PhD Student Filipa Martins at filipa.martins@usj.edu.mo or call to 66583685.

APPENDIX B:

Example of the letters created in 3 languages for all the three schools, to have the approvals of parents. The school names are hidden since they requested confidentiality.



聖若瑟大學
UNIVERSITY OF SAINT JOSEPH

Permission for participation in the Research Project,
"Game Design for Creativity in Education: Audio-visual and Tangible User Interaction Models"
Doctoral in Science and Technology of the Arts - *Interactive Art*

22nd of March 2017, Macau

To all the parents who have their children enrolled in K1 to K3 levels at the [REDACTED]

Dear parents,

We are writing this letter to request your permission to include your child in a research project that will take place at the end of March until the end of June 2017 spanning various public and private schools in Macau.

This research project involves them participating in a research study where we will analyse how your child plays and interacts with digital and tangible games with educational components. This will be achieved by filming them during each session in order to record data and analyse it afterwards.

The psychologist of the school, their classmates, as well as the research student in-charge of this study will accompany your child during these sessions.

The study revolves around understanding how they, as individuals and as a group, will use their creativity, playfulness and collaboration to resolve the game. We hope to observe a myriad of solutions in each session, how creativity changes through time and training and ultimately how the physical and the digital worlds assist in the creative learning of your child.

We hope to obtain positive results from this study, which will be a valid scientific contribution to the development and future of learning in Macau Schools.

All the films and sound captured will be given to the school and will not be publicized or shared in any social platform or television. However this study may be used for presentation purposes in the form of photos and data graphs in research papers part of the research project mentioned above. If photos are used they will not show facial recognition of the child.

Thank you,
Best Regards,

☐ Agree

☐ Don't Agree

Approved by

Álvaro Barbosa
Dean at the Faculty of Creative Industries
| USJ - PhD Supervisor | UCP
http://www.usj.edu.mo/en/faculty_directory/alvaro-barbosa

Approved by

Carlos Sena Caires
Head of the Design Department at the
Faculty of Creative Industries | USJ - PhD Co-Supervisor | UCP
http://www.usj.edu.mo/en/faculty_directory/carlos-sena-caires

Signed by

Filipa C. A. Martins de Abreu
PhD Student | UCP
Senior Lecturer | USJ
http://www.usj.edu.mo/en/faculty_directory/filipa-martins



參與下述研究計劃的同意書。

「Game Design for Creativity in Education: Audio-visual and Tangible User Interaction Models」

博士學位學程 - 文學的科學及技術 - 互動藝術 (Doctoral in Science and Technology of the Arts - Interactive Art)

澳門二零一七年三月二十二日

致全體就讀於二龍喉中葡小學幼

親愛的家長 台鑑，

此信函旨在邀請 貴家長同意閣下之子女參與於澳門各所公立及私立學校舉辦的一項研究計劃，計劃執行時間由二零一七年三月底至六月底。

本計劃旨在於分析參與者在含有教學元素的虛擬及實體遊戲中遊玩及互動之過程。這將會通過拍攝記錄 貴子女在各個場合的情況以作數據收集及後期分析。

學校的心理師、同學們，以及負責執行本研究計劃的人員將會在全部場合陪同 貴子女。

本研究將會探討受試者於個人及團體中運用其創造力、趣味性及團隊合作來解決遊戲中疑難。我們希望藉此觀察在各個場合中的不同疑難解決的方法，受試者的創造力在不同時間、訓練中的變化、以及最終實體及虛擬世界對於 貴子女的創造性學習的幫助。

我們預料本研究將會獲得正面的成果，將會對澳門學校的發展及未來學習情況提出有效的科學貢獻。

所有拍攝記錄的映像及聲音將會遞交至其所屬之學校，且並不會放映及分享於任何社交平臺或電視上。但是，本研究的資料或許以照片及資料圖表形式於論文或上述研究計劃進行發表。貴子女可被辨識的臉部將不會呈現在使用的照片上。

專此候覆。

順頌

時祺

☐ 同意

☐ 不同意

由准許

Álvaro Barbosa
創意工業學院院長 | 聖若瑟大學
博士指導老師 | UCP

由准許

Carlos Sena Caires
創意工業學院設計系主任 | 聖若瑟大學
博士共同指導老師 | UCP

簽名

Filipa C. A. Martins de Abreu
博士班學生 | UCP
資深講師 | 聖若瑟大學



Autorização para participar no Projecto de Investigação.

"Design de Jogos para a Criatividade na Educação: Audio-Visuais e Modelos Tangíveis de Interação do Utilizador"
Doutoramento em Ciências e Tecnologia das Artes – Arte Interactiva

Macau a 22 de Março de 2017

Para todos os pais que têm filhos matriculados nos níveis pré-primário (infantil) na

Caros pais,

Vimos por este meio solicitar a vossa autorização para incluir os seus filhos num projecto de investigação que terá lugar a partir do final de Março até ao final de Junho de 2017 abrangendo várias escolas públicas e privadas em Macau.

Este projecto de investigação visa a que os participantes façam parte de um estudo onde iremos analisar como os seus filhos jogam e interagem com jogos digitais e tangíveis com componentes educativas. Isto será conseguido através de filmagens que serão feitas durante cada sessão (3 a 4) a fim de obter dados tangíveis para serem analisados mais tarde.

O psicólogo da escola, os colegas, tal como o estudante de doutoramento responsável por este estudo, acompanharão os seus filhos durante estas sessões.

Através deste estudo tentaremos compreender como os seus filhos, individualmente e em grupo, utilizam a criatividade, a jogabilidade e a colaboração para resolver cada jogo. Esperamos obter através da observação e da explicação dos jogos aos vossos filhos, várias soluções em cada uma das sessões, como por exemplo, como é que a criatividade ao longo do tempo do estudo se modifica, e como, com o treino desta ela se transforma. Para finalizar, observaremos também como é que o mundo físico e o digital se auxiliam na aprendizagem criativa dos participantes.

Esperamos obter resultados positivos deste estudo, que sejam um contributo científico válido para o desenvolvimento e o futuro da aprendizagem nas Escolas de Macau.

Todas as filmagens e sons capturados serão dados à Instituição de ensino e não serão divulgados ou partilhados em nenhuma plataforma social ou televisiva. No entanto, este estudo poderá ser usado para fins de apresentação sob a forma de fotos e gráficos de dados em documentos de pesquisa. Caso as fotos sejam usadas, garantimos que elas não terão o reconhecimento facial das crianças.

Muito obrigado,
Melhores cumprimentos.

☐ Concordo ☐ Não Concordo.

Approvado por

Álvaro Barbosa
Director da Faculdade de Indústrias Criativas | USJ
Orientador de Doutoramento | UCP

Approvado por

Carlos Sena Caires
Coordenador do Departamento de Design da Faculdade de Indústrias Criativas | USJ
Co-Orientador de Doutoramento | UCP

Assinatura de

Filipa C. A. Martins de Abreu
Aluna de Doutoramento
Professora | USJ

APPENDIX C:

Photo of all the approvals from parents.

The image shows three sheets of parent approval forms for a research project. The forms are arranged side-by-side, showing the Chinese, English, and Portuguese versions. Each form includes a header with logos of the University of Saint Joseph and the Faculty of Creative Industries, followed by a title, a body of text explaining the project, and a signature section at the bottom with checkboxes for 'Agree' or 'Disagree'.

Chinese Form (Left):

參與下述研究計劃的
「Game Design for Creativity」
博士學位課程 - 文學的

澳門二零一七年三月二
致全體就讀於二龍喉中

親愛的家長 台鑒，

此信函旨在邀請 貴家
由二零一七年三月起至

本計劃旨在於分析參與
女在各個場合的情況以

學校的心理師、同學們

本研究將會探討受試者
察在各個場合中的不同
界對於 貴子女的創造

我們預料本研究將會獲
所有拍攝記錄的映像及
本研究的資料或許以照
在使用的照片上。

專此候覆。

順頌
時祺

由准許

Alvaro Barbosa
創意工業學院院長 | 聖若
博士指導老師 | UCP

English Form (Middle):

Permission for participation in
"Game Design for Creativity in
Doctoral in Science and Techn

22nd of March 2017, Macau
To all the parents who have th

Dear parents,

We are writing this letter to re
of March until the end of June

This research project involves i
with digital and tangible games
order to record data and analys

The psychologist of the school,
child during these sessions.

The study revolves around und
collaboration to resolve the gar
time and training and ultimate

We hope to obtain positive res
of learning in Macau Schools.

All the films and sound capture
television. However this study
papers part of the research prc

Thank you,
Best Regards,

Approved by

Alvaro Barbosa
Dean at the Faculty of Creative
[USJ] - PhD Supervisor | UCP
http://www.usj.edu.mo/en/faculty/_barbosa

Portuguese Form (Right):

Autorização para participar no Projecto de Investigação.
"Design de Jogos para a Criatividade na Educação: Audio-Visuais e Modelos Tangíveis de Interação do Utilizador"
Doutoramento em Ciências e Tecnologia das Artes - Arte Interactiva

Macau a 22 de Março de 2017
Para todos os pais que têm filhos matriculados nos níveis pré-primário (infantil)

Caros pais,

Vimos por este meio solicitar a vossa autorização para incluir os seus filhos num projecto de investigação que terá lugar a partir do final de Março até ao final de Junho de 2017 abrangendo várias escolas públicas e privadas em Macau.

Este projecto de investigação visa a que os participantes façam parte de um estudo onde iremos analisar como os seus filhos jogam e interagem com jogos digitais e tangíveis com componentes educativas. Isto será conseguido através de filmagens que serão feitas durante cada sessão (3 a 4) a fim de obter dados tangíveis para serem analisados mais tarde.

O psicólogo da escola, os colegas, tal como o estudante de doutoramento responsável por este estudo, acompanharão os seus filhos durante estas sessões.

Através deste estudo tentaremos compreender como os seus filhos, individualmente e em grupo, utilizam a criatividade, a jogabilidade e a colaboração para resolver cada jogo. Esperamos obter através da observação e da explicação dos jogos aos vossos filhos, várias soluções em cada uma das sessões, como por exemplo, como é que a criatividade ao longo do tempo do estudo se modifica, e como, com o treino desta ela se transforma. Para finalizar, observaremos também como é que o mundo físico e o digital se auxiliam na aprendizagem criativa dos participantes.

Esperamos obter resultados positivos deste estudo, que sejam um contributo científico válido para o desenvolvimento e o futuro da aprendizagem nas Escolas de Macau.

Todas as filmagens e sons capturados serão dados à Instituição de ensino e não serão divulgados ou partilhados em nenhuma plataforma social ou televisiva. No entanto, este estudo poderá ser usado para fins de apresentação sob a forma de fotos e gráficos de dados em documentos de pesquisa. Caso as fotos sejam usadas, garantimos que elas não terão o reconhecimento facial das crianças.

Muito obrigado,
Melhores cumprimentos.

Concordo ☒ Não Concordo. ☐

Approved por

Alvaro Barbosa
Director da Faculdade de Indústrias Criativas | USJ
Orientador de Doutoramento | UCP

Approved por

Carlos Sena Caires
Coordenador do Departamento de Design da Faculdade de Indústrias Criativas | USJ
Co-Orientador de Doutoramento | UCP

Assinatura de

Filipa C. A. Martins de Abreu
Aluna de Doutoramento
Professora | USJ

APPENDIX D:

Explanations of the experimental study sent to schools. Dates were modified accordingly to their availability.



CATOLICA PORTO UNIVERSITY OF SAINT JOSEPH

Research Project: "Game Design for Creativity in Education: Audio-visual and Tangible User Interaction Models"
Doctoral in Science and Technology of the Arts - Interactive Art

EXPERIMENTAL STUDY

PART 1

OSMO Game System

DATES: October to December 2017
LOCATION:
LEVELS: K1 to K3 / 3 to 6 years' old

Setup – 3 cameras and 1 surround sound recorder – research student will do this.
8:30 am
– 30 min

Starting time
9:00 am
– Participants start to come in the room and start to sit.

Explanations and Instructions
– 5 minutes
– *Inside the room should only be the Psychologist (or the school responsible, no teacher should be inside the room), the research student and the students.*

K2 – DAY 1 – OCTOBER 30

K2 – group 1 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K2 – group 2 // 3 participants
– 15 minutes – 3 kids at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K2 – group 1 & 2 // 6 participants
After the 2 sessions – 30 minutes
– Free play

K1 – DAY 2 – OCTOBER 31

K1 – group 1 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K1 – group 2 // 3 participants

October 2017 | 1



CATOLICA PORTO UNIVERSITY OF SAINT JOSEPH

– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K1 – group 1 & 2 // 6 participants
After the 2 sessions – 30 minutes
– Free play

K3 – DAY 3 – NOVEMBER 1

K3 – group 1 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K3 – group 2 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K3 – group 1 & 2 // 6 participants
After the 2 sessions – 30 minutes
– Free play

Table Summary – Structure

FIRST DAY K2 / 4 – 5 years' old	SECOND DAY K2 / 3 – 4 years' old	THIRD DAY K3 / 5 – 6 years' old
– 6 participants total – 15 minutes each session	– 6 participants total – 15 minutes each session	– 6 participants total – 15 minutes each session
First Group // 3 participants 1 Boy - 2 Girls	First Group // 3 participants 1 Boy - 2 Girls	First Group // 3 participants 2 Boys - 1 Girl
1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces
2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces
Second Group // 3 participants 2 Boys - 1 Girl	Second Group // 3 participants 2 Boys - 1 Girl	Second Group // 3 participants 1 Boy - 2 Girls
1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces
2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces
3rd Session Free Play // 6 participants 3 Boys - 3 Girls	3rd Session Free Play // 6 participants 3 Boys - 3 Girls	3rd Session Free Play // 6 participants 3 Boys - 3 Girls
- print (no paper games) + physical pieces	- print (no paper games) + physical pieces	- print (no paper games) + physical pieces
- digital (no game system) + physical pieces	- digital (no game system) + physical pieces	- digital (no game system) + physical pieces

PART 2

October 2017 | 2



CATOLICA PORTO UNIVERSITY OF SAINT JOSEPH

TIGGLY Game System

DATES: October to December 2017
LOCATION:
LEVELS: K1 to K3 / 3 to 6 years' old

Setup – 3 cameras and 1 surround sound recorder – research student will do this.
8:30 am
– 30 min

Starting time
9:00 am
– Participants start to come in the room and start to sit.

Explanations and Instructions
– 5 minutes
– *Inside the room should only be the Psychologist (or the school responsible, no teacher should be inside the room), the research student and the students.*

DAY 1 – K1 – TBC

K1 – group 1 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K1 – group 2 // 3 participants
– 15 minutes – 3 kids at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K1 – group 1 & 2 // 6 participants
After the 2 sessions – 30 minutes
– Free play

DAY 2 – K2 – TBC

K2 – group 1 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K2 – group 2 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K2 – group 1 & 2 // 6 participants
After the 2 sessions – 30 minutes
– Free play

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CATOLICA PORTO UNIVERSITY OF SAINT JOSEPH

DAY 3 – K3 – TBC

K3 – group 1 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K3 – group 2 // 3 participants
– 15 minutes – 3 participants at the same time – with paper and physical objects
– 15 minutes – the same 3 participants at the same time – with digital interface and physical objects

K3 – group 1 & 2 // 6 participants
After the 2 sessions – 30 minutes
– Free play

Table Summary – Structure

FIRST DAY K1 / 3 – 4 years' old	SECOND DAY K2 / 4 – 5 years' old	THIRD DAY K3 / 5 – 6 years' old
– 6 participants total – 15 minutes each session	– 6 participants total – 15 minutes each session	– 6 participants total – 15 minutes each session
First Group // 3 participants 1 Boy - 2 Girls	First Group // 3 participants 1 Boy - 2 Girls	First Group // 3 participants 2 Boys - 1 Girl
1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces
2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces
Second Group // 3 participants 2 Boys - 1 Girl	Second Group // 3 participants 2 Boys - 1 Girl	Second Group // 3 participants 1 Boy - 2 Girls
1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces	1st Session - print (no paper games) + physical pieces
2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces	2nd Session - digital (no game system) + physical pieces
3rd Session Free Play // 6 participants 3 Boys - 3 Girls	3rd Session Free Play // 6 participants 3 Boys - 3 Girls	3rd Session Free Play // 6 participants 3 Boys - 3 Girls
- print (no paper games) + physical pieces	- print (no paper games) + physical pieces	- print (no paper games) + physical pieces
- digital (no game system) + physical pieces	- digital (no game system) + physical pieces	- digital (no game system) + physical pieces

PART 3

DATES: September to January
DIGITAL SURVEY

SURVEY (About Games and Creativity)
– All K1, K2 and K3 students - to be sent home for parents to answer.

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APPENDIX E:

Photos of all the drawings of the kids - part 2 - session 1 to 3.



APPENDIX F:

Links for all the videos and photos online:

Access is restricted.

<https://drive.google.com/drive/u/1/folders/18dhhqTiBEHnthNcuqkzIYwOBY2jzCtCX>

