Interactive Cultural Narratives: Unveiling the Potential of the 3D Serious Game Maker Tool for Kristang Culture

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Abstract

Culture is a cornerstone of identity, yet many cultures face the risk of fading into obscurity despite efforts to preserve them through various mediums. Leveraging the concept of 3D serious games and basing the research on key learning theories like the maker pedagogy and multiliteracies theory, this research aims to educate children about culture by developing a 3D game maker tool that implements key elements of the researched learning theories. The goal is to empower users aged 12 and older to effortlessly create serious 3D cultural games in a first-person view, enriching the experience with IoT and AI features. Additionally, the tool facilitates gameplay of games crafted using the same platform, fostering social interaction and aligning with effective forms of learning.

Methodologically, an iterative design process was employed, starting with the creation of initial prototypes and interviews to discern optimal features and design principles. The tool was refined based on insights gathered from existing literature on serious game design guidelines, prioritizing user-friendly accessibility, and ensuring the learning theories are properly implemented. In the final trial, participants engaged in crafting 3D serious games using the tool, juxtaposed against a control group utilizing a conventional 2D storyboarding tool. Subsequently, participants immersed themselves in a serious game experience exploring Kristang culture, with learning gain, memory, and knowledge retention meticulously evaluated.

Despite its focus on Kristang culture, the tool's adaptable nature suggests its potential applicability to diverse cultural contexts. Findings indicate that the tool improved user experience and learning outcomes for Kristang cultural heritage education compared to control methods. However, limitations such as a small sample size and system constraints were encountered.

Research implications delve into the potential of the 3D serious game maker tool as an effective educational tool for children to learn about culture, contributing to the broader understanding of utilizing innovative technology for cultural education among younger demographics. Moreover, design guidelines established in the study lay a foundation for future research endeavors seeking to develop effective educational tools with a significant impact on learning outcomes.

Practically, integrating the tool into classroom settings holds promise for fostering immersive and interactive cultural education experiences, augmenting traditional instruction, and facilitating collaborative learning. This research introduces an innovative educational tool that combines elements of the maker movement with experiential learning paradigms, addressing the gap of lack in 3D cultural maker educational tools that combine learning theories into their framework. This research aims to implement those learning theories into an engaging 3D game maker tool specifically for the Kristang culture.

In conclusion, the development of this innovative 3D serious game maker tool represents a significant stride towards cultural education for younger generations. Embracing the opportunities presented by this tool can pave the way for more inclusive and dynamic approaches to cultural learning, empowering children to explore, create, and celebrate diverse cultural narratives in a digital age.

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LIST OF ABBREVIATIONS

Abbreviation	**Full Description**
AI	Artificial Intelligence
AR	Augmented Reality
CLIL	Content Language Integrated Learning
DGBL	Digital Game based Learning
ESL	English as Secondary Language
FR	Functional Requirements
GB	Gigabyte
GPIO	General Purpose Input/Output
GUI	Graphical User Interface
HCI	Human Computer Interaction

HUD	Heads Up Display
HVAC	Heating, Ventilation and Air Conditioning
IoT	Internet of Things
MDA	Machine Dynamics and Aesthetics
ML	Machine Learning
NFR	Non-Functional Requirements
NGO	Non-Governmental Organization
PARC	Paro Alto Research Center
PHP	Hypertext Preprocessor
PL	Personalized Learning
RAM	Random Access Memory
RFID	Radio Frequency Identification
UI	User Interface

UK	United Kingdom
US	United States
USB	Universal Serial Bus
VR	Virtual Reality

Chapter 1 Introduction

1.1 Background of Study

Culture is a defining aspect of people's lives, influencing behaviours, customs, and beliefs. For many individuals, their culture forms an integral part of their identity and lifestyle, underscoring its importance and the need for preservation (Hofstede & McCrae, 2004; Barbuti, 2018). For generations, the documentation of history has played a vital role in safeguarding cultural heritage and transmitting knowledge about ancient civilizations to subsequent generations. Narratives spanning from ancient Egyptian dynasties to the Roman Empire and Viking sagas have been disseminated through diverse mediums such as museums, academic texts, and cinematic productions. However, not all cultural legacies have received equitable recognition.

An illustrative case is the Nyonya culture in Malacca, Malaysia. While widely celebrated for its culinary traditions, much of its broader customs and traditions remain obscured from mainstream awareness. Despite sporadic documentation in scholarly literature and curated displays in museums, a significant portion of the populace remains uninformed about the depth and complexity of Nyonya heritage (Oh, et al., 2019; Yusof, et al., 2014). Nevertheless, scholarly inquiry into minority cultures, exemplified by studies like Ng and Karim's (2016) investigation into Nyonya culinary practices, signifies a growing interest in understanding and preserving these cultural nuances. This suggests that while certain cultural identities may be marginalized, there exists a dedicated cohort of individuals committed to elucidating and conserving their cultural heritage.

In today's ever-evolving technological landscape, museums are compelled to adapt and embrace innovative technologies. With the widespread availability of highly advanced search engines, individuals can effortlessly access information at their fingertips, anytime and anywhere. Barbuti (2018) emphasized on digital cultural heritage preservation. The idea is to use the innovative technologies to keep track and store all the necessary data and information about all the artifacts and the history of mankind rethinking the strategies used to achieve a long-term digital preservation of cultural heritage. Consequently, museums must explore ways to present information in a manner that resonates with tech-savvy visitors. Notably, Batchelor's (2011) intriguing research highlights how American culture has been disseminated to other nations through the exportation of technology products and the global reach of the media industry. Innovative solutions like the interactive exhibit developed by Not and Petrelli (2019) allows users to create their own personalized museum experiences through a set of interactive tools are a step towards the right direction, however, the solution was limited, requiring a long time to implement and requiring a team. This phenomenon underscores the significant influence of technology companies and entertainment conglomerates in shaping cultural narratives beyond national borders.

Despite technology not yet being fully integrated into museums and cultural institutions, there have been notable innovations in this field. In the United States, some cultural institutions have experienced a surge in engagement by incorporating technology into their exhibits (Song, 2017). These innovations include more interactive exhibits within museums and the development of virtual tours of historic sites. For instance, Egypt has launched five free virtual tours of its ancient historical sites, allowing users worldwide to explore these landmarks from the comfort of their homes, as a response to the Covid-19 pandemic (Machemer, 2020). These tours provide comprehensive information about the sites and offer interactive experiences, attracting a wide audience and contributing to the preservation of cultural heritage. However, despite these advancements, there remains a gap in fully leveraging technology to bridge the divide between cultural institutions and their audiences. Contemporary challenges to cultural awareness extend beyond the declining interest of younger generations. The unique circumstances of the Covid-19 pandemic have exacerbated these challenges faced by museums and cultural institutions. In this context, it becomes imperative to identify and implement alternative digital solutions.

Serious games, also known as applied games, are interactive experiences that extend beyond mere entertainment, allowing players to engage in activities aimed at practicing skills and achieving specific objectives (Muñoz, et al., 2022). Unlike traditional video games focused solely on entertainment, serious games prioritize learning while still incorporating elements of enjoyment. Often referred to as educational games, they have gained popularity as effective tools for teaching various subjects such as mathematics, languages, religion, and history. The utilization of serious games in education aims to enhance the quality and efficiency of information delivery to students. This approach has led to the emergence of approaches like gamification, which incorporates game elements into non-game applications in an effort to enhance the user-experience and better capture the user's attention and motivate them. Research by Guia et al. (2013) highlights the success of video games in captivating users' interest, while Sanzana et al. (2023) underscore the utility of video games as educational tools, particularly in keeping students engaged during the learning process.

The integration of Internet of Things (IoT) technology has been instrumental in digitalizing cultural learning within museums. As devices connect to the internet, they seamlessly become part of the growing IoT network. This network extends beyond specialized sensors to include everyday devices like laptops and smartphones, which have become integral components of this expanding ecosystem. While traditional perceptions of IoT often revolve around dedicated sensors, it's essential to acknowledge that smartphones, in their ubiquitous role, serve as dynamic sensors within this interconnected landscape. Continuously transmitting and receiving data, these personal devices play a significant role in shaping the multifaceted and evolving fabric of the IoT network. Furthermore, the increasing adoption of IoT technologies presents new opportunities for game design within museums (Quah & Ng, 2021; Huang, et al., 2021). Burrus (2014) included IoT in a game authoring tool to improve the player experience by including physical sensors in the games developed. IoT is much bigger than what many people perceive. Huang et al. (2021) devised a card game solution that synthesizes design knowledge for IoT serious games in museums, aiming to facilitate rapid idea generation for non-experts in this field.

A critical need persists for innovative approaches that can reignite interest and engagement among younger generations in cultural learning. Several studies have demonstrated the beneficial impacts of games on cultural learning (Mortara, et al., 2014; Ye, et al., 2020). It is believed that these games can help in understanding cultural heritage in ways that traditional methods cannot. For an instance, they create methods for the public to explore and understand heritage sites that otherwise would be inaccessible or have been lost to history (DaCosta & Kinsell, 2023). Cultural heritage games can also act as a bridge between cultures, enabling people to share and learn from each other's cultural traditions. Empathy with a game character and plot may be very helpful for people to gain a better understanding of different cultures, and develop an appreciation for the diversity of human cultures, and the beauty and value of nature, architecture, art, and heritage (Mortara, et al., 2014; Camuñas-García, et al., 2023). The younger generations are more tech savvy and video games are more integrated into their activities, which makes it a good medium to teach culture through.

Multiliteracies pedagogy, proposed by The New London Group in 1996, responds to the increasing influence of technology and digital innovations in education (The New London Group, 1996). Traditional pedagogy falls short in addressing the demands of a globalized world, where literacy extends beyond reading and writing to encompass 21st-century skills. Recognizing this shift, efforts to enhance education led to the implementation of multiliteracies pedagogy in the classrooms, as demonstrated by innovative approaches such as peer assessments using social media networks and graphical tools like PowerPoint.

Maker pedagogy, characterized by interactivity, open-ended exploration, and a student-driven focus (Bullock & Sator, 2015), finds its roots in established learning theories such as Jean Piaget's constructivism and Seymour Papert's constructionism (Ackermann, 2001). This educational approach emphasizes learning through hands-on experiences and active participation (Papavlasopoulou, et al., 2017). Serious game authoring tools offer a promising avenue for incorporating maker education principles into learning environments (Mehm, et al., 2012). By engaging in game creation, students not only learn by doing but also by making decisions, solving problems, and expressing their creativity. This process aligns closely with the principles of maker pedagogy, fostering a collaborative and interactive learning environment where students take ownership of their learning journey. Thus, serious game authoring tools can serve as effective tools for promoting maker education and empowering students to become active creators of knowledge.

A few educational game creation platforms have been proposed, but they are for creating simple games such as trivia and are limited to 2D (Molnar & Kostkova, 2016) or the popular Scratch platform that teaches children programming using visual blocks (SCRATCH) , or pixelated 3D such as in Minecraft Education (Mojang, 2024).

Crafting first-person, 3D experiences introduce a level of complexity that surpasses the integration of other technologies. This technical intricacy, however, is met with the understanding that overcoming these challenges opens unique avenues for cultural learning. By focusing on this aspect, the research seeks to not only address existing gaps but also underscore the transformative potential of a serious 3D game maker tool as a medium for interactive and immersive cultural education of children.

1.2 Problem Statement

In the era of globalization, the convergence of diverse cultures underscores the importance of mutual respect and heightened awareness. However, certain cultures confront the looming threat of extinction, either due to waning interest among younger generations or the overwhelming tide of globalization itself. Fostering a renewed interest among the youth in their cultural heritage and lineage is paramount for cultivating respect in a globalized world, thereby emphasizing the significance of cultural exchange, particularly for younger demographics.

Serious games utilizing immersive 3D technologies offer exciting potential for engagement. Although serious 3D games have proven effective in cultural education, the absence of representation for all races and cultures underscores the need for inclusivity (Luigini, et al., 2020; DaCosta & Kinsell, 2023). However, they often prioritize mainstream cultures, inadvertently perpetuating their dominance while overshadowing lesser-known ones. Additionally, the development of these games requires proficient programming skills, posing a barrier to entry for many creators. Consequently, the imperative of cultural awareness and mutual respect remains unaddressed, with many underrepresented cultures fading into obscurity, such as the Mandaean culture in Iraq, facing a palpable fear of cultural extinction (Nickerson, et al., 2009). It is imperative to instil in the younger generation an understanding of their roots and traditions, positioning them as stewards of cultural preservation in an increasingly interconnected world (Muravevskaia, et al., 2016).

While existing 3D serious game authoring tools exist, they typically require coding knowledge and lack a focus on creating cultural games. Creating a game authoring tool tailored for teaching and learning among the younger generation necessitates extensive research and thorough requirement gathering. Essentially, such a tool should empower any individual, even without prior programming knowledge, to share cultural stories by creating games and enabling others to play them. This process involves a rich level of interaction during both game creation and gameplay. Leveraging the maker movement and experiential learning, the development of a tool integrating these methodologies emerges as a potential solution (Schad & Jones, 2020; Naul & Liu, 2019). However, existing 3D serious game authoring tools are scarce, lacking comprehensive requirements and research, particularly in the realm of cultural education (Hintze & Masuch, 2004; Ververidis, et al., 2019; Mehm, et al., 2012). With thorough research, a culturally engaging game authoring tool can foster creativity, collaboration, and learning while celebrating diverse cultural narratives among the younger generation.

This research proposes the development requirements for a 3D serious game maker tool aimed at bridging the gap in cultural learning. It solidifies this proposal by creating a 3D serious game authoring tool specifically designed for cultural education, with a focus on the Kristang culture as a case study. While the tool is tailored to Kristang culture, the methodology used in its development can be adapted to other cultural contexts. Additionally, the research aims to assess the potential impact of the 3D serious game authoring tool on the user experience and immersion and on the learning gain, knowledge retention, and memory retention. By examining the efficacy of maker education in this context, the research seeks to introduce an innovative tool that fills the gap which is shown as a lack in 3D serious cultural game making tools. Results from this research can provide insights on whether the approach in this research is feasible, asses its impact and identify key points to improve in future research.

1.3 Research Questions

The research questions that this study aims to address are:

RQ1: What are the prevailing methods utilized in teaching cultural aspects, and in what aspects do they demonstrate limitations or inadequacies?

RQ2: How can the deficiency in 3D serious game maker tools tailored for cultural games be effectively addressed?

RQ3: What strategies are effective in designing a 3D serious game maker tool that resonates with younger generations, specifically in the context of cultural education?

RQ4: What is the user experience and degree of immersion reported by users when utilizing the designed tool?

RQ5: What are the educational impacts of employing the designed tool for cultural education, particularly in terms of learning enhancement, memory retention, and knowledge acquisition?

1.4 Aims and Objectives

The aim of this research is to develop an educational tool for the tech-savvy younger generation, integrating maker and multiliteracies pedagogy to facilitate cultural learning through serious game creation. This study explores the development of a 3D serious game maker tool tailored for cultural knowledge transfer and assesses its impact on learning outcomes, knowledge retention, and memory retention among younger users.

The following objectives aim at answering the research questions:

O1: To conduct a comprehensive literature review to analyse existing serious games developed for cultural heritage, identify available tools within this domain, and determine areas of deficiency or limitations.

O2: To design and develop a user-friendly 3D serious cultural game maker tool specifically tailored for the younger generation, ensuring it does not necessitate any programming or game development expertise.

O3: To engage in interviews with a diverse range of experts, educators, and education university students to gather feedback and insights throughout the development stages of the prototype. Synthesize this feedback with existing serious game design guidelines to formulate comprehensive design guidelines for the tool.

O4: To evaluate the user experience and immersion levels of the developed tool through user trials. Gather feedback from participants regarding various aspects of using the tool to create their own serious 3D cultural games.

O5: Assess the effectiveness of the developed tool in terms of learning gain, memory retention, and knowledge retention among a selected group of participants. Measure these outcomes after participants engage with a demo game created using the tool.

1.5 Course of Study

This research is divided into three main phases. The first phase involves gathering requirements to design the game-making tool. This is achieved through literature research, expert and stakeholder interviews, feedback collection on the initial prototype, analysis of results from a serious cultural game about Malacca developed prior to this research and conducting a small evaluation trial on a popular game-making tool called Scratch, with a specific focus on testing its integration with Raspberry Pi. A small Human-Computer Interaction (HCI) competition was held at the University of Nottingham to test the Raspberry Pi extensions in Scratch 3. Feedback was collected from participants through a paper survey to gather their opinions on a specific set of questions. The primary goal of this experiment was to determine the advantages of using Scratch with Raspberry Pi, leveraging the benefits of adding IoT to the game-making tool while mitigating any drawbacks. The experiment also served as a test on how to conduct trials involving Raspberry Pi and determine the optimal trial methodology.

The second phase is an extensive process focusing on the design and development of the tool through participatory design. Participatory design entails engaging all pertinent stakeholders throughout the design and development phases to ensure alignment with the end-users' requirements. This approach has become common among software developers in recent years as marketing strategies shift towards being more customer centric. The end users of this research are students aged approximately 12 and above, with teachers or supervisors overseeing their use of the tool, making their feedback crucial. Given the tool's intended use as an educational support tool, classrooms are the typical setting, involving both students and teachers in its usage.

The tool's development initially occurred in three stages:

1. Developing level design features to enable users to design their own levels.
2. Developing logic features to allow users to add logic to their games and create a functional game flow.
3. Adding Quality-of-Life (QoL) features such as integrating ChatGPT as a virtual assistant to help users come up with stories, incorporating RFID card sensory input as a small IoT addition, and including a story archive with stories for users to base their games on.

In addition to the participatory design approach, this tool's development was inspired by the multiliteracies pedagogy first developed by the New London Group in 1994 (The New London Group, 1996). This pedagogy addresses how globalization and technology innovation have increased diversity in classrooms, requiring educational approaches that cater to various cultural backgrounds and perspectives. The tool's development was also influenced by the maker education movement, focusing on creating a tool that facilitates learning through hands-on making experiences. Due to resource constraints, this research focused on a specific culture as a case study, with the Kristang culture being the primary focus. Therefore, the final prototype included assets tailored for this culture. Ideally, scaling this research would involve incorporating assets from diverse cultures.

The last phase of this research involves evaluating the tool created in a main user trial, focusing on two main aspects. The first aspect is evaluating the tool in terms of user experience and immersion while students create their serious cultural games. The second aspect is evaluating the tool's impact on learning culture, mainly through assessing students' learning about the Kristang culture via a serious game designed using the tool. The main metrics for evaluating learning impact include learning gain, memory retention, and knowledge retention.

1.6 Significance of Study

Serious games have emerged as a powerful medium for interactive and immersive education. They hold promise for educating individuals about culture, especially younger generations who are more attuned to video game formats. However, the development of such games is often challenging, and many cultures remain underrepresented in the serious gaming sphere. Existing 3D game-making tools typically have steep learning curves and require programming expertise, limiting accessibility, particularly among younger demographics.

This research seeks to bridge this gap in 3D serious game development tools by introducing an innovative educational platform rooted in maker pedagogy and multiliteracies principles. Designed to be user-friendly and engaging for younger audiences, the tool enables them to create their own 3D serious cultural games. Drawing on existing literature and incorporating feedback from experts and users, the tool facilitates learning through both instruction and hands-on experience, aligning with the principles of effective learning as outlined in the Learning Pyramid by the National Training Laboratory (Loveless).

Furthermore, the tool incorporates additional features such as RFID card sensory input, introducing a level of physical interaction beyond conventional mouse and keyboard controls. This inclusion offers insights into the potential integration of Internet of Things (IoT) technology into serious games, while the integration of ChatGPT as a virtual assistant enhances accessibility.

The tool's focus on the Malaccan Kristang culture serves as a compelling case study, featuring specific 3D assets tailored to this cultural context. The findings of this research illustrate how such a tool can benefit not only the maker movement and serious games development but also cultural heritage education more broadly. By empowering users to craft their own customizable learning experiences, the tool embodies educational pedagogies that encourage innovation and active participation in the learning process.

1.7 Scope and Limitation of Study

This study explores the different educational pedagogies that focus on immersive learning and integrating technologies, making the maker and the multiliteracies pedagogies ideal learning theories to research on. It focuses on how to include elements of those learning theories into creating an educational tool that can empower the younger generations into learning about culture. By creating a tool that allows 3D serious cultural games to be created without development knowledge the younger users can get to experience a very interesting way of learning about culture not available to them before. New media like IoT was integrated slightly into the tool and by adding ChatGPT a state-of-the-art technology is integrated to further enhance the experience.

Acknowledging inherent limitations is also an important part of any research. Specifically, limitations such as technological constraints which resulted in some features not being implemented, resource constraints which limited the amount of 3D assets that could be included, sample size constraints which limited the number of participants in the trial, and generalizability of the results by assuming that the results on the Kristang culture will work for other cultures.

However, the research also identifies avenues for future exploration. These include expanding the tool's cultural repertoire, refining features based on user feedback, and exploring broader applications of maker pedagogy and multiliteracies principles in educational technology. Ultimately, the study contributes to the advancement of cultural heritage education and innovation in educational technology through the development and assessment of this novel educational tool.

1.8 Main Contributions

This research yields two significant contributions that propel both research and technology forward. Drawing upon established educational frameworks and pedagogies, the study develops a functional prototype that not only validates the efficacy of maker and multiliteracies pedagogies but also demonstrates their capacity to yield favourable outcomes. The resulting tool is pivotal as it provides a foundation for future exploration and enhancement, establishing the concept of the research framework used in this work. Extensive research, interviews, and user feedback informed the tool's feature design, ensuring alignment with educational frameworks and optimal user experience. This rigorous process yielded comprehensive design guidelines for 3D serious cultural game-making tools, constituting the second major contribution of this research. These guidelines will serve as invaluable resources for future researchers and developers seeking to advance this burgeoning field of inquiry.

Chapter 2 Literature Review

This section reviews previous works done related to HCI, usage of HCI in cultural settings and museums, serious games and their usage in education and cultural games, IoT and its applications in serious games, including cultural games. Moreover, it will review the learning theories that are used in this research alongside research on game authoring tools, design guidelines to develop serious games and the inclusion of AI in game authoring tools. Finally, it includes a summary section explaining what was reviewed in this section and how this research will utilize this research and move further.

2.1 Introduction

This research will focus on general HCI, the importance of HCI and how HCI has been integrated into museums for better experiences for the visitors. It will also focus on serious games, what they are, how they have been used in terms of an educational aspect and cultural aspect. Furthermore, it will shed some light on learning theories such as maker pedagogy and multiliteracies, which serve as foundational inspirations for the development of a game authoring tool. It further investigates state-of-the-art game authoring technologies, exploring the integration of artificial intelligence and Internet of Things (IoT) functionalities. Ultimately, the research aims to propose a novel approach—a cultural game authoring tool—leveraging these innovative technologies to enrich interactive cultural experiences.

2.2 Background

Human Computer Interaction (HCI) essentially concerns how humans interact with computers. It constitutes a fundamental aspect of this research, as it delves into how young people perceive the use of technology. The evolution of HCI interfaces has been marked by significant milestones over the decades. Initially emerging in the 1970s, HCI primarily centered around Graphical User Interfaces (GUIs) pioneered by researchers at the Xerox Palo Alto Research Center (PARC) (Fekete, 2009). These interfaces, though initially intended for research purposes, laid the groundwork for a revolution in computer graphics, leading to the sophisticated GUIs we interact with daily (Butler, et al., 1999).

As HCI has progressed, its focus has expanded beyond traditional screen interfaces to encompass a wide array of interaction modalities, including sensors and emerging technologies. Designing HCI systems is a multifaceted endeavour, intertwining principles from software engineering, computer graphics, and psychology. Modern GUIs reflect a deep understanding of human psychology, optimizing user experience through intuitive design and strategic placement of interface elements.

Contemporary approaches such as use-case driven software engineering emphasize the centrality of human factors and user activity in interface design (Jacobson, et al., 1992). Additionally, the separation of system design into distinct layers, as proposed by Foley et al. (1990), provides a structured framework for developers and designers to create user-centric interfaces. Costa et al. (2021) presents a systematic literature review on the use of ontologies in the field of HCI, revealing that while ontologies have been utilized for over 25 years mainly for knowledge representation and reasoning, their frequency of use has increased in the last decade.

Serious games, another fundamental aspect of this research, represent a paradigm shift in gaming, prioritizing educational objectives over entertainment. This emerging genre has given rise to "Digital game-based learning" (DGBL), where computer video games serve as powerful educational tools. While DGBL encompasses a spectrum of educational and gaming elements, serious games distinctly focus on educational outcomes (Prensky, 2001). DGBL means the use of computer video games as an educational tool. While some researchers argue that DGBL is actually a balance between educational elements and gaming elements that form a game (Nussbaum & Beserra, 2014), others have agreed that DGBL has two separate but main components; an entertainment component which would include all the aspects of a game that makes it fun, and a training/educational component which includes all aspects of a game that actually teaches or trains the players in a game (Bellotti, et al., 2013). Serious games are one type of DBGL and they more primarily focused on education while there are other games that are primarily focused on entertainment but still contain educational elements in them (Stewart, et al., 2013) for example, a game that is very popular and has been around for nearly a decade, Assassin’s Creed, in which the player plays as an assassin in a captivating story about different histories and monumental events in the human history such as the French Revolution, the Greek mythology.

These games can be categorized based on their primary objectives, including knowledge transfer, skill-based learning, and behavioural change. From teaching mathematics and language to simulating critical training scenarios in military and healthcare settings, serious games offer diverse applications with tangible real-world impacts. According to All et al. (2016), serious games can be classified into one of three. Firstly, games that target knowledge transfer or aims for cognitive learning outcomes (Stewart, et al., 2013), like the game developed by Castellar (2015) to teach maths or to teach language. Secondly, games that have the main objective of teaching a new skill; those are usually referred to as "skill-based learning outcomes" games. Furthermore, these games tend to be used for more practical applications like military and hospital training where a simulated training course would prove to be very beneficial without any risk to personnel or environment (Kosmides, et al., 2018; Sanzana, et al., 2023). However, they are not only limited to critical situations training, but have been used for training managerial skills as well (Corsi, et al., 2006; Kretschmann, 2012).

Moreover, serious games have emerged as effective tools for promoting awareness and influencing behavior in various domains, such as environmental conservation and public health. Their ability to engage users while imparting valuable knowledge makes them invaluable assets for organizations and initiatives focused on social change (All, et al., 2016). While the other two types of games are very important, this type of serious games is probably the hardest to develop but also the most important as it acts to improve the quality of life. Applications of such games can be seen in environmental awareness campaigns, energy saving campaigns. Building on that, Pokric et al. (2015) developed a game that promotes awareness about pollution in a city. Energy awareness games that promote energy saving attitudes and rewards players accordingly were mentioned in (Medina, et al., 2014) and (Garcia-Garcia, et al., 2017). Behavioural change games are very common amongst Non-Government Organizations (NGO)s who use them frequently to raise awareness. PING (Neys, et al., 2012) is a game that was used to promote awareness and to change the behaviour of people towards poverty. As seen how diverse the range of applications can get, Baronowski et al. (2008) has also shown how a behavioural change game could be used to promote good eating habits in younger kids.

Internet-of-Things (IoT) is an additional aspect of this research as this research investigates whether including IoT will be useful for engagement. The IoT has revolutionized connectivity, creating a network of interconnected devices ranging from smartphones to sensors. Initially conceptualized by Kevin Ashton in 1999, IoT has since become pervasive, with billions of devices connected to the internet. In the context of the maker movement, IoT plays a pivotal role, enabling makers to integrate physical sensors and devices into their projects. This convergence of digital and physical realms empowers makers to innovate and create products with enhanced capabilities and functionalities. The proliferation of IoT devices presents vast opportunities for innovation and integration across industries (Gartner, 2017). As IoT adoption continues to grow, it is poised to reshape various aspects of daily life, from smart homes and cities to industrial automation and healthcare.

2.3 Overview on Learning Theories and Frameworks

This section discusses short briefs about the different learning theories that inspired this maker tool. It starts by discussing the maker pedagogy, a phenomenon that started in 2005 in the United States (US) and is helping change the way we view education which focuses on learner centered approaches and experiential learning frameworks. It then discusses differences between constructivism and constructionism and how they are both very helpful in educating students in a useful manner. Lastly, it discusses the multiliteracies pedagogy which inspires teaching to not be specific and generalised to a particular race or culture, but rather to be inclusive of all cultures so that all students can relate to and get inspired by the teaching process, paving the way for personalized learning.

2.3.1 Maker Pedagogy

Maker pedagogy has been gaining momentum in the US since early 2005 with more institutions and organizations forming and teaming up to provide this new form of education to young children. It focuses more on teaching the learners the skills necessary to solve the problem which makes it more direct and straightforward. Therefore, the maker pedagogy is more interactive, open-ended and student driven. Its hands-on applications allow the learners more freedom to use their imagination in creative and innovative ways to find solutions to real-life problems. Over the years, several organizations have formed to start the Maker Education initiative as seen in Maker Ed, MakerEducation.com, Educator Innovator and such.

The maker education is not only limited to kids but is applicable to almost any age range. To elaborate, maker education is not a type of education that must be implemented in schools or day cares, it is a type of education that can benefit anyone, anywhere. To shed more light on maker education, there are two main keywords commonly associated with maker educations. The first being the term makers which basically indicates any participant in a maker education activity like a project. The second term is makerspace which indicates any gathering or event where different people come together to work on various problems and try to solve it in their creative solution. One of the best advantages of makerspaces is how it connects different people from different backgrounds together to solve a common problem.

Programmers, engineers, welders, marketers, would group together to brainstorm, design, and implement a product that solves a particular issue. One such example is the Vancouver Maker Foundation which has been founded since 2011 and has been blooming in success ever since. The foundation has organized several events with its first Vancouver Mini Maker Fair taking place in the June of 2011 and attracting over 100 makers which is very impressive (Smith, 2014). Maker education has since thrived in Vancouver with many more maker spaces being opened all over the city in addition to Maker camps and Maker cities.

A learner-centered approach derived from maker pedagogy emphasizes active engagement, creativity, and hands-on problem-solving. In this approach, students are at the center of the learning process, taking an active role in constructing their knowledge through making, tinkering, and experimenting. Learning is personalized, with students pursuing projects that interest them and addressing real-world problems. This fosters a sense of ownership and motivation, encouraging students to explore, innovate, and learn through doing. The teacher acts as a facilitator, providing guidance and resources, while students collaborate, iterate, and reflect on their learning experiences. This approach nurtures critical thinking, creativity, and practical skills, preparing students for complex, real-world challenges (González-Pérez & Ramírez-Montoya, 2022).

Tabares and Boni (2022) explores the integration of maker culture into formal education, particularly in STEM fields, through the establishment of open and collaborative learning ecosystems (OCLEs). Drawing from a case study involving educators, students, and external stakeholders across four countries, it highlights the potential of maker culture to enhance STEM education and address societal challenges. Despite the benefits, challenges such as organizational resistance in higher education institutions (HEIs) are noted, emphasizing the need for institutional recognition and support for successful implementation. This article examines the integration of Education 4.0 components into 21st-century skills frameworks to meet the demands of Industry 4.0 and address post-pandemic challenges (González-Pérez & Ramírez-Montoya, 2022). The study advocates for the development of educational models that foster complex-reasoning competencies and auto-systemic thinking to tackle societal issues effectively (González-Pérez & Ramírez-Montoya, 2022). This paper examines the potential of the Maker movement to benefit students from disadvantaged backgrounds, and while providing Maker Spaces is a step, the research suggests it's not enough (Leonard, et al., 2022). A mixed methods study with year 7 students showed positive impacts on STEM attitudes but varied across different constructs and depended on initial attitudes and proposes a reference framework to consider equity when designing Maker experiences (Leonard, et al., 2022). Doyle (2023) offers practical strategies and insights for educators to support students transitioning from traditional, teacher-centered classrooms to more student-driven learning environments. With a focus on understanding student attitudes and providing guidance on navigating learner-centered practices, the book equips educators with the tools to foster independent learning, communication skills, self-evaluation, and lifelong learning habits among their students (Doyle, 2023).

2.3.2 Constructivism and constructionism

The maker education was built on existing learning theories like Jean Piaget's constructivism theory which he founded during his various education works and Seymour Papert's constructionism theory. Despite having two different names and being different theories, both the theories have the same goals but different means of reaching them as discussed by (Ackermann, 2001). Piaget was more concerned with children and how they think; he discussed in detail how children have different views of the world and how they adapt their way of thinking to suit their current needs. Furthermore, Piaget discussed how most of the learning happens during an experience rather than something being told to them in what he described as "teaching is always indirect". The maker education is inspired by Piaget's theory that learning occurs through an experience and interaction with the real world, therefore, maker education focuses on allowing the learners to deal with a real problem and create an actual solution to the problem rather than giving them instructions to memorise on how to solve a particular problem.

The main difference between Piaget's constructivism theory and Papert's constructionism theory is that Piaget did not take into consideration the role and influence of personal preferences or styles, as well as the role of context and media in the learning process (Ackermann, 2001). Simply put, Papert believed that while learning occurs during an experience, it also occurs "while building a public entity, be it a sandcastle or a theory of the universe" (Harel & Papert, 1991). Papert's approach inspired the maker education due to its heavy reliance on learning through making which also helps in understanding how different media when used in particular contexts by various different people can generate and transform different creative ideas (Ackermann, 2001).

An experiential learning approach derived from constructivism and constructionism emphasizes learning through direct experience and active participation in meaningful activities (Kolb & Kolb, 2009). The meta-cognitive model for experiential learning seamlessly integrates meta-cognitive strategies with experiential learning principles to elevate learning effectiveness (Kolb & Kolb, 2009). Central to this model is the promotion of conscious awareness and regulation of one's learning processes. Key components encompass understanding one's learning self-identity, embracing the learning spiral's iterative nature, adapting learning styles to optimize outcomes, and cultivating conducive learning spaces. Within this framework, learners take an active role in monitoring and controlling their cognitive processes, employing strategies for planning, monitoring, and evaluating their learning.

Rooted in the principles of constructivism, the experiential learning approach asserts that learners construct their own understanding and knowledge of the world through experiences and reflecting on those experiences (Kolb, 2014). Constructivism, championed by Jean Piaget, highlights the importance of learners actively constructing their knowledge through interaction with their environment. Building on this, Seymour Papert's constructionism adds that learning is most effective when learners are involved in creating tangible artifacts, such as models, digital projects, or other physical objects (Papert, 1994). In this context, learners engage in hands-on activities that require them to apply concepts in practical, real-world situations, promoting deeper understanding and retention of knowledge. Thus, an experiential learning approach derived from these theories involves active engagement, hands-on projects, reflection, contextual learning, and collaboration. Learners actively participate in learning activities, create tangible artifacts, reflect on their experiences to derive meaning and insights, learn in real-world contexts, and often work together, sharing ideas and perspectives. This approach not only promotes knowledge acquisition but also develops critical thinking, problem-solving skills, and creativity by immersing learners in active, project-based learning environments (Papert, 2020). Furthermore, pioneering scientist Papert (2020) discusses the importance of teaching children with computers and acknowledges the creative methods involved in doing so.

This systematic literature review identifies key elements supporting the effectiveness of experiential learning: active participation, situated knowledge, exposure to novel experiences, problem-based learning, and critical reflection (Morris, 2020). These findings align with Kolb's (2014) experiential learning theory, emphasizing learning through active engagement, contextualized knowledge acquisition, risk-taking in new situations, practical problem-solving, and reflective observation. The proposed revision to Kolb's model incorporates these elements, suggesting that experiential learning consists of contextually rich concrete experiences, critical reflective observation, contextual-specific abstract conceptualization, and pragmatic active experimentation (Morris, 2020). McClaren et al. (2020) emphasizes the importance of tailoring education to individual specialties, peer interactions for contextualizing knowledge, and gaining experience through observation and interaction with experts in their field. Furthermore, they stress the critical need for tailored support and opportunities for experiential learning in continuing education.

Cronje (2020) critiques current definitions of blended learning for overlooking the fundamental aspect of learning itself, advocating for a shift towards definitions grounded in learning theory. This paper proposes a model that integrates behavioural and constructivist learning, exploring the possibility of simultaneous occurrence (Cronje, 2020). Through research validation, the Cronje (2020) presents a framework incorporating context, theory, methodology, and technology, aiming to provide a comprehensive definition of blended learning that aligns with principles of knowledge management.

Analyzing student attitudes and experiences through a constructivist lens in this study reflects a commitment to active engagement and knowledge construction, central tenets of the learner-centered approach (Suh & Ahn, 2022). Furthermore, the metaverse's customizable and interactive features offer opportunities for tailoring learning experiences to individual student needs, thereby promoting personalized learning within a student-centered educational framework (Suh & Ahn, 2022). The significant prevalence of metaverse experiences among elementary school students, with 97.9% reported engagement by Suh and Ahn (2022), highlights its potential relevance for learner-centered education. By elucidating the process through which students derive insights from critical incidents within an experiential entrepreneurship course, Crosina et al. (2023) enhance scholarly understanding in the realms of experiential learning, experiential entrepreneurship education, and the cultivation of an entrepreneurial mindset.

2.3.3 Multiliteracies Pedagogy

The multiliteracies pedagogy was first proposed by The New London Group (1996) when they suggested that technology and digital innovations have become widespread and the need to utilise them in education is necessary. They noticed that the traditional classroom pedagogy is not enough, given the increasing globalisation in the schools and the classrooms. Literacy is no longer about knowing how to read and write, but rather it needs to involve the 21st century skills that the industry demands nowadays. Recent calls for critical education regarding social and digital media emphasize the need for 21st-century media and literacy skills (Cope & Kalantzis, 2023). Twenty-five years after the New London Group's influential article (1996) introduced "multiliteracies," two original members Cope and Kalantzis (2023) revisit and update the concept for the digital age and propose a new transpositional grammar while maintaining the core aim of promoting educational justice through literacy education. Hong and Hua (2020) review the concepts of literacy, multiliteracies, and multimodality in education, emphasizing the importance of expanding literacy beyond traditional print mediums and adopting multiliteracies pedagogies to accommodate diverse learning needs, including digital and online literacies, in classroom practice.

A personalized learning approach derived from multiliteracies pedagogy emphasizes tailoring education to meet the diverse cultural, linguistic, and learning needs of each student. Proposed by the New London Group (1996), multiliteracies pedagogy expands the traditional notion of literacy to include multiple modes of communication and representation, reflecting the varied ways in which students engage with content and express understanding. This approach recognizes that literacy involves a range of skills, including visual, audio, spatial, and digital literacies. In a personalized learning environment inspired by multiliteracies, education is customized to accommodate individual learners' backgrounds, preferences, and abilities (Zhang, et al., 2020). It incorporates students' cultural experiences and knowledge into the curriculum, utilizes various forms of media and communication, empowers students to take control of their learning, and ensures that teaching strategies and materials are inclusive of all students. Additionally, it encourages collaborative activities where students can share their unique insights and learn from each other. This approach fosters a more engaging, relevant, and effective educational experience by recognizing and valuing the diverse ways in which students learn and communicate, aiming to develop a broad range of literacy skills and preparing students to navigate and contribute to an increasingly complex and interconnected world. Employing critical interpretive synthesis, Zhang et al. (2020) discerned two overarching themes concerning personalized learning across diverse fields of study. These themes encompassed exploration into (a) the influence of different technologies and (b) contextual factors affecting the integration of personalized learning (Zhang, et al., 2020).

Salinas and De-Benito (2020) explores the implementation of personalized learning pathways in teacher training, utilizing a mixed-methods approach within design-based research. By enabling students to configure their own learning pathways using an interchangeable learning sequence structure, the approach fosters autonomy, self-direction, and collaborative skills, thus enhancing the learning experience in initial teacher training programs (Salinas & De-Benito, 2020). Alamri et al. (2020) conducted a qualitative comparison study to assess the effectiveness of personalized learning (PL) activities in supporting students' psychological need satisfaction (fulfillment of autonomy, competence, and relatedness) and intrinsic motivation (engaging in tasks for inherent satisfaction) in an online course compared to a traditional one-size-fits-all model. The results indicated that implementing PL principles in online courses has the potential to enhance students' psychological need satisfaction and intrinsic motivation, particularly in terms of autonomy and competence (Alamri, et al., 2020). Additionally, students found the PL interventions engaging and effective in addressing their learning needs and interests (Alamri, et al., 2020). The potential of personalized learning to shift the focus of higher education from teacher-centered to learner-centered environments was explored in an integrative literature review encompassing personalized learning theory, supportive learning technologies, current practices, and case studies of technology models in higher education (Alamri, et al., 2021). Findings highlighted three technological models facilitating personalized learning in blended environments, an increasing adoption of personalized learning in higher education, and a need for more data-driven research on its effectiveness (Alamri, et al., 2021).

Involving digital aspects into the classrooms is pivotal to increasing the quality of education. The multiliteracies approach included using peer assessments by students using social media networks to include a digital aspect and using graphical tools for presentation such as PowerPoint (Chen, et al., 2021). The results were convincingly better than the traditional approach when the writing samples from the students were assessed demonstrating that the multiliteracies pedagogy had a positive effect.

In a very interesting approach that utilizes elements of IoT and is also inspired by the multiliteracies pedagogy, Sylla et al. (2019) creates the MobeyBou, a creative and interactive multi-cultural storytelling tool where the students get to share their own cultural stories using physical blocks connected to a computer. The multiliteracies pedagogy is being used here by using innovative technologies in teaching, using different media elements like audio and video but also using touch sensors to interact.

LearnWeb2.0 by Marenzi and Zerr (2012) is a searching and collaboration environment intended to share resources which was later used in two Content and Language Integrated Learning tools. Cultural awareness is especially helpful when involved with groups of diverse cultures, as different immigrant pre-teens managed to cope better due to their participation in different multiliteracies activities, which helped ease them into a diverse cultural lifestyle in the United Kingdom (UK) (Boivin, 2016). Another well-known maker-based platform for sharing one's interactive story is SCRATCH where a player uses 2D objects and animations to create games. The platform is said to make kids smarter with technical literacy (Biggs, 2013). It is important to note that cultural awareness does not have a definitive structure or approach but is an idea upon which other innovations could be built upon.

Kalantzis and Cope (2023) discusses the impact and evolution of the influential 1996 publication "A Pedagogy of Multiliteracies: Designing Social Futures" by the New London Group, tracing its origins, the subsequent work of its members, and the development of the multiliteracies concept over the decades. Bazinet (2020) examines the multiliterate benefits of using digital literature and digital games at an English language college in Quebec, revealing significant positive implications for multiliteracy development through digital games. Flint et al. (2020) explores a qualitative study to let participants reimagine their identities. A multiliteracies theoretical framework offers a critical perspective for lifelong learning, engaging with cultural diversity, technology, and other factors.

Drawing from a pilot study and a Social Sciences and Humanities Research Council (SSHRC) Insight research study, this article explores how such a framework can inform more critical and creative pedagogical approaches for adolescents and adults (Holloway & Gouthro, 2020). While multiliteracies have been less commonly utilized in adult learning contexts, Holloway and Gouthro (2020) argues for its benefits, particularly in addressing issues of globalization, diversity, and technology impact. Holloway (2021) further explores the experiences of pre-service and in-service teachers involved in The Multiliteracies Project, focusing on their development of web platform posts and multimodal pedagogical tools within lesson plans to promote a multiliteracies approach across diverse content areas. Using constructivist grounded theory, findings highlight themes including fostering creativity through design, enhancing disciplinary literacy, and broadening pedagogy with digital literacies (Holloway, 2021). Despite perceived demands, participants benefited from engagement in Learning by Design, suggesting its potential for integrating multiliteracies in education (Holloway, 2021). Despite the framework's lack of popularity in Indonesia, the study by Christanti et al. (2023) demonstrates its effectiveness when properly utilized by knowledgeable teachers. By structuring activities based on the MPF dimensions and guiding students through experiencing, conceptualizing, analyzing, and applying cognitive functions, the lecturer successfully fosters critical thinking skills among students, further evidenced by students' assignments, which showcase their ability to provide thoughtful comments supported by reasoning, data, and evaluations (Christanti, et al., 2023). Additionally, the positive response from students, with 96.5% satisfaction on average, underscores the framework's potential for enhancing education in Indonesia (Christanti, et al., 2023). Overall, the learning theories discussed in this section have proved to be very beneficial and very suitable to include in serious games considering their emphasis on creativity, adaptability, and personalization therefore making them ideal learning theories for this work.

2.4 Human-Computer-Interaction (HCI) in Culture

Many research studies have demonstrated how using new combined multimedia approaches have improved experiencing CH. Technologies such as first-person based immersions, AR, VR and Mixed Reality (MR) are being used for education, exhibitions, virtual museums. Mentioning HCI interfaces in museums might not make sense at first because most of us would think of museums as places where cultural artifacts exist behind glass boxes for people to see, and that is where the interaction ends. However, there has been a surprising number of new innovations in the recent years to add technology and interactivity into museums to make them more appealing to younger generations. While Taxen (2004) tried to increase interactivity in museums by setting guidelines on how to involve the visitors in designing exhibitions, HCI still means that a computer has to be involved in the process. Interaction in museums could bring about the learning-by-doing which could enhance learning and which has already been used in science museums more than historic museums as suggested by (Meisner, et al., 2007) which inspired them to create Tangible User Interfaces for museums (Horn, et al., 2008).

Bekele (2018) mentions that using such innovative technologies allow user-centred presentations and make CH digitally accessible even when physical presence is not possible. It is important to include digital innovations into museums as artifacts are usually only allowed to be looked at, not touched, and interacted with. This is due to many factors like the objects being fragile, the size might be too big or too small or for the simple fact that artifacts are too valuable to allow people to handle them (Not, et al., 2019).

Tangible interactions with game-based learning have recently become the focus and is in an early growth stage in Singapore and Southeast Asia. This research study focused on game-based learning on Singaporean CH where real interactive board games were introduced to children aged 8-10 years old for teaching them about religious monuments and would complement the CH education of primary social studies program in Singapore (Ching, et al., 2015). Cheng (2017) evaluated the use of VR by adapting the 3D game *Crystallize* to teach bowing in Japanese greetings which is an embodied cultural interaction and the study carried out on 68 participants showed it increased the sense of involvement of participants in Japanese culture.

In an effort to create an interactive HCI interface where users can interact with the artifacts and get guided information about the artifact, yet at the same time preserve the artifact by using digital augmentation of the centre piece, Not et al. (2019) designed an interactive plinth that was displayed in the Italian National War Museum in Rovereto, Italy. The plinth included IoT elements as part of its interface with elements like Radio Frequency Identification (RFID) sensors being placed and the user of audio output as well as videos to guide the visitors about the artifact once they start interacting with it. This case study has accomplished success on its trial as this new type of interactive with the artifact allowed the use to gain more empathy towards the people who actually used said object but also increase social interaction amongst the visitors (Not, et al., 2019). This definitely creates a more memorable experience for the users and allows them to remember what they saw and learned in their visit to the museum. Despite using innovative technologies like IoT, the approach lacked in the way of delivery information and relied on traditional text and audio.

The main aspect of using digital technologies in learning about cultural heritage is to bring out the edutainment value and appeal to heterogenous public, specifically the younger generations. The term edutainment basically means educational entertainment where various multimedia approach such as video games, television and such are intended for education but is also of an enjoyable experience. 360◦ videos were displayed through VR were intended to preserve the old bridge diving tradition in Bosnia which mentioned some historical information with cultural connections (Selmanovic, et al., 2020). Selmanovic (2020) specifies that there was a reward system linked to this research as after viewing the materials, the participants would have to answer a series of quiz questions and upon successful completion, they would be able to experience a virtual dive and the case study demonstrated successful output in communicating ideas and in preserving heritage.

Incorporating digital technologies in museums demands attention because interactions with artefacts and collections can be made possible without having preservation issues. Interactive installations can interest more visitors to learn and understand various cultures. In this research, a Pan Flute from Egypt that dates back to 700 A.D. was recreated virtually and would convey information about its history, musicology, and iconography (Pretto, et al., 2020). This installation at a museum was then tested on groups of experts of music, archaeology and such and it obtained results that showed it was a convenient approach for interaction in terms of museum context for cultural learning.

Figure 2.2.1 Visitors in the museum using the interactive plinth designed by (Not, et al., 2019)

(Marshall, et al., 2016) used smart tangible replicas of artifacts in an interactive museum exhibition. Notably, an authoring tool was developed to create custom visitor experiences (Not & Petrelli, 2019). The tool used IoT features and had several interfaces involved with it. The results of using this tool were satisfactory with most of the participants benefiting from using it and finding it interactive and interesting. However, the tool required a group of participants from different fields of expertise. It was not developed to be able to design experiences quickly, as the first trial took two days to complete, and the participants included skilled professionals.

2.5 Serious Games in Education

Research has shown that games are a very effective method of educating students (Sanzana, et al., 2021). Boyle et al. (2011) discusses the role of psychology in understanding the impact that computer games have on education. They presume that the reason serious games are an effective tool in education is due to the fact that the players are immersed in the game. The learning is taking effect in an active way and the players are constantly focused on the game and trying to solve the problems. This method increases the attention while the learning process is taking place and makes serious games a great tool for education. By reviewing 129 games they were categorised into different categories, with some being labelled under entertainment and some being labelled under learning and serious games (Connolly, et al., 2012). Moreover, each game had its own learning outcome which varied with each game. Motivational gain was the aim for some, improving cognitive skill, behavioural change, social skills were the aim for some of the others. This vast range of topics and outcomes are only more evidence that serious games are changing the way education is perceived and leading the evolution in the educational sector.

The conclusion of such a thorough review of serious games was that the most common experimental approach for games that were targeting learning gains like knowledge, cognitive, motor and psychological was a quasi-experimental approach (Connolly, et al., 2012). A quasi-experimental approach does not select participants by random but rather selected groups that participate. This is logical given the fact that the aforementioned gains are very specific gains and will most likely be targeting a specific set of people to whom that gain is most relevant. Surveys, on the other hand, were more common in usage when it came to the social skills and motivational gain, highlighting the fact that surveys are a good approach to use in opinionated topics like motivation (Connolly, et al., 2012).

The study provides evidence that integrating serious games in VR form with traditional lectures can significantly enhance learning outcomes, supporting the use of serious games in education as effective pedagogical tools (Sanzana, et al., 2021). However, there is less consensus in the literature on the cognitive benefits of IVR, with results sometimes indicating it is an effective tool for learning, not an effective tool for learning, or similar to other instructional media in its impact on learning outcomes, which underscores the need for more research on the efficacy of serious games in education (Lawson & Martella, 2023). Sanzana et al. (2023) investigates the use of two gamified virtual labs in teaching biology and chemistry, exploring how gamified elements can be effectively incorporated into higher education curricula to determine if immersive gamified virtual labs can serve as effective pedagogical tools by promoting low-risk active learning and student engagement. The study demonstrates that gamified virtual labs can significantly enhance student engagement and knowledge development, supporting the integration of serious games into higher education as effective tools for active and interactive learning (Sanzana, et al., 2023). This study introduces an innovative training method for facility management and maintenance of Thermal-Energy-Storage (TES) chiller plants using a serious 3D game that improves decision-making by allowing personnel to actively learn to manage TES chiller plants (Sanzana, et al., 2024). The immersive learning experience employs a first-person perspective in a computerized simulation, letting players assume the role of facility managers to address maintenance issues in a controlled setting. The results suggest that serious 3D games are effective educational and training tools, enhancing engagement and decision-making skills in facility management, thus supporting the broader use of serious games in educational and professional training contexts (Sanzana, et al., 2024).

2.6 Internet of Things in Education

The integration of IoT into education has been through various medias and forms, one of which are games. Despite being a new technology, IoT is yet to reach its full potential due to its many various forms. It could be used in thousands of possibilities and ways and that makes its applications rather diverse, which could lead to an increase in the time it takes to get widespread. Choudhary et al. (2015) discuss the psychology of IoT and how most of the people are not really tech savvy which makes it hard for a new technology to become widespread easily. The paper goes on and discusses further the potential of IoT in the modern gaming industries and how IoT will revolutionize the way we view video games (Choudhary, et al., 2015). Similarly, using IoT in education is a rather new technology and therefore is not widespread, but has a huge potential to revolutionize the way we view education.

Further research in the ways IoT has been incorporated into education applications can be seen in the literature review by Kassab et al. (2019) which analysed 89 research papers and summarised the findings. IoT could be used to aid education as a means of maintaining attendance by using simple RFID cards and RFID card readers (Kassab, et al., 2019; Gul, et al., 2017). Tan and Ng (2022) explores the potential of mobile technology to enhance cultural learning and engagement through the design and development of "The Story of Praya Lane," a prototype story game app created with the involvement of cultural heritage stakeholders to preserve and share stories of the Kristang community in Malacca. Consequently, the study provides design guidelines for future interactive story games aimed at supporting cultural education and underscores the significant role of IoT in education by demonstrating how interconnected technologies can create immersive, engaging, and educational experiences (Tan & Ng, 2022).

Despite the introduction of numerous digital storytelling authoring tools aimed at improving learning, there is a lack of systematic reviews informing how these tools have been designed, developed, and implemented in education. This paper addresses this gap by presenting a systematic review of 91 studies, highlighting the technology and use trends related to authoring tools in educational digital storytelling (Quah & Ng, 2021). Furthermore, the analysis identifies best practices in designing these authoring tools, synthesized as design guidelines for future researchers and practitioners in the field (Quah & Ng, 2021).

While there are means of IoT being integrated into educational applications, they are not serious games with IoT, as far as this research has uncovered. Educational aspects are not just in terms of teaching school kids about their syllabus, but rather is it is any gain in knowledge and applies to any age group. This research focuses on analyzing whether integrating IoT into a cultural game authoring tool can be an interesting and innovative approach in maker-based education for culture (Abdulrazic, et al., 2022). The study involved 39 participants aged 18-28 creating mini games with SCRATCH and Raspberry Pi, followed by a survey assessing their experience and satisfaction with the integration process (Abdulrazic, et al., 2022). The findings emphasize the importance of developing user-friendly methods for integrating IoT with game authoring tools like SCRATCH to enhance engagement and effectiveness in Maker-based education, suggesting further exploration and refinement in this area for successful implementation of IoT in educational settings (Abdulrazic, et al., 2022). Integrating IoT into serious games can enhance interactive learning experiences and cultural awareness, making it a valuable tool in educational settings. IoT significantly enhances experiential learning by creating interactive and immersive educational environments. Additionally, IoT facilitates remote learning, providing access to educational content and virtual labs from anywhere. Through Do-It-Yourself (DIY) IoT kits and project-based learning, students gain practical experience in building and programming IoT devices, fostering creativity and technical skills (Abdulrazic, et al., 2022).

2.7 Internet of Things in Serious Games

The Internet of Things (IoT) has been a major research focus for two decades, revolutionizing many fields by overcoming longstanding challenges (Ahmad, et al., 2022; Quah & Ng, 2021). Recently, integrating miniature sensing devices in serious games has emerged as a trend, enhancing educational and informative experiences in areas such as education, healthcare, and physical training. This paper surveys IoT-enabled serious games, examining their development, current state, and the challenges that remain to be addressed (Ahmad, et al., 2022). However, research has explored incorporating IoT into serious educational games, with promising examples demonstrating its potential to raise awareness about energy consumption through interactive experiences (Medina, et al., 2014). Moreover, gamification elements were also used with IoT to help in reducing the consumption of energy by modifying the Heating, Ventilation and Air Conditioning (HVAC) systems in buildings in (Papaioannou, et al., 2017) and (Mylonas, et al., 2017). These modifications could be in terms of switching the lights on or off, modifying the temperature or switching the HVAC system on or off (Garcia-Garcia, et al., 2017).

Integrating IoT into serious games could include using RFID cards, pressure sensors, light sensors, motion sensors, sound sensors and the list goes on. However, implementing any of these sensors into a game is a tricky and complex task, but when achieved could be pivotal. WandBot used RFID tags to teach vocabulary words to students in a school (Miglino, et al., 2013). It followed a competitive format wherein every student had to control a robot in a race. The idea is that the students need to touch their Magic Wand, which is basically an RFID reader onto the card that best resembles the word that they are seen. The student that manages to touch the correct card before the others gets their robot to move forward a bit. Ultimately, the student that gets their robot to the finish line first, wins.

To show more variations of how IoT has been integrated into different kinds of IoT games, we would like to shed light on ICEBERG (Kosmides, et al., 2018), a role-playing online game that accommodates more than player. The game focuses on placing sensors around a particular area to detect the different behaviours of the users at that area. Good behaviour like switching off lights before leaving the room or using the stairs instead of the lift will reward the players inside the game by allowing their Yeti to have minions to help him build igloos on his ice land and so on. The concept is very great and entertaining and unlike traditional games that require the users to sit down and play it, this game allows the users to go about their daily routine while at the same time monitoring their behaviours and rewarding them for good actions and penalising them for the wrong ones.

The increasing use of IoT technologies in education opens up new avenues for innovative learning tools, as demonstrated by the development of a card game to aid in the creation of IoT-based serious games for museums. This approach highlights how IoT can enhance educational experiences by providing interactive and engaging methods for idea generation and concept development (Huang, et al., 2021).

2.8 Serious Games in Culture

Serious games in the cultural context offer a unique opportunity to convey knowledge, motivate, and engage players through immersive storytelling (Mortara, et al., 2014). Bekele et al. (2018) mentions that using such innovative technologies allows user-centered presentations and makes CH digitally accessible even when physical presence is not possible. Games following a "Story-Mode" are prevalent, spanning genres like adventure, shooting, mystery, and thriller. Cultural games, such as Icura (Froschauer, et al., 2010), Roma Nova (2012) and a gamified mobile sensing app by Tan and Ng (2022) immerse players in Japanese, Roman and Kristang cultures, respectively, providing an interactive and experiential learning environment. The potential of serious cultural games lies in their ability to blend education with entertainment, offering an engaging way to explore and understand diverse cultural heritages.

Looking at previous cultural games to reflect more on the type of games and the genres used, Icura (Froschauer, et al., 2010) presents a very good example of a cultural game that teaches the player about the Japanese culture, etiquettes, and habits. Through realistic 3D scenes the player gets to experience the Japanese culture in an interesting way rather than reading about it in books or listening to lectures. The game follows a story mode followed by some tests and could be classified as an adventure/mystery game. The Roman culture is one of the most famous cultures in the world so there is no surprise that serious games about their culture were developed. A notable game is Roma Nova (2012) where the game focuses more on the player engaging with the Roman community and learning with them. It follows the genre of a social game more than an adventure or mystery because the social aspect in the game is strong to give the player the feel of being a part of the Roman community during that time. The game should be praised for its efforts to create a realistic environment with random social interactions between the characters in the game and with the player. The game story Kingdom Come: Deliverance is driven by actual historical facts and more surprisingly, the locations of the towns on the game map are accurate with respect to their actual physical counterparts (Dingman, 2018). Furthermore, the game is extremely realistic and contains most of the impressive features that get gamers to play games for hours. The advanced questing system, interesting and gripping storylines, and advanced combat system are just some of the few features that make this game very impressive and very educative at the same time.

Figure 2.2 A snippet of ICURA developed by (Froschauer, et al., 2010)

Figure 2.3 Roma Nova screenshot (Anon., 2012)

However, serious cultural games are not only developed by researchers who do not have the mean nor the ability to create a huge scale professional game. Unlike the previous example, Kingdom Come: Deliverance is a cultural game that hits almost all the briefs when it comes to a complete game, that is still serious and contains plenty of learning material for any history enthusiast. The game is developed by Warhorse Studios, a Czech-based game studio and is focused on the Czech Republic during the 1400s. The story is driven by actual historical facts and more surprisingly, the location of the towns in the game is at the same location those towns were in in real life (Dingman, 2018). Furthermore, the game is extremely realistic and contains most of the impressive features that engage gamers to play games for hours. Advanced questing system, interesting and gripping story lines, advanced combat system are just some of the few features that makes this game very impressive and very educative at the same time.

The game gives the player the full experience where the player gets to choose how he wants to play the game, being a villain or a savior. Interactions with characters affect the relationships with those characters and subsequentially the flow of the story. Different weapons have different strengths and weaknesses, and so does armor. Player starts as a blacksmith's son and fights his way for glory in a thrilling, realistic, historically accurate first-person role-playing game. Unfortunately, however, due to the fact that the game is commercial, no research was done to show the impact of the game on cultural gain.

Figure 2.4 A screenshot of Kingdom Come: Deliverance by Hayden Dingman (Dingman,2018)

A renowned game studio Ubisoft developed a popular game series Assassin's Creed and has recently incorporated Egyptian, Nordic i.e., Viking, and Greek mythology in a cultural setting (Ubisoft, 2020; Maguid, 2018). The Assassin's Creed game series grasped the attention of many individuals and surely showed how 3D games in a cultural setting can be a successful way of cultural storytelling as they are now proceeding to make a story on Baghdad (Shukla, 2022; Bellingham, 2022). The "Discovery Tour" of Assassin's Creed allows the player to roam in a non-violent and educational background setting where Ancient Egypt and Ancient Greece filled their game worlds with guided tours and museum-style exhibits (Reparaz, 2021). Discovery Tour: Viking Age utilizes a more narrative-driven approach where players are able to personify as different Viking and Anglo-Saxon characters, who have a unique storyline designed in a way to bring players closer to historical events and discovering about that culture (Reparaz, 2021). The Discover Tour in the context of Ancient Greece uses and discusses how it is important to be in players', students', and teachers' hands in cultural exploration and awareness (Maguid, 2019). However, it is very costly to develop a specific-cultural centric game such as the Assassin's Creed game series, and instead, a more publicly accessible game authoring tool will be applicable in other cases. Young children will be more aware of diverse cultures if they have an accessible tool like SCRATCH (Team, 2021) to make games related to various cultures and tell or experience a story. Zeiler and Mukherjee (2021) discuss about introducing video game development as a cultural and creative industry in India and points out that game studios focusing Indian cultural heritage are increasingly including elements of history, art, and architecture. However, this research was aiming more about a specific cultural video game development, rather than having a game authoring tool for different cultural games to allow anybody to share their heritage (Zeiler & Mukherjee, 2021).

2.9 Game Authoring Tool

This section will describe and evaluate some of the game authoring tools available nowadays, how AI has helped some tools achieve better user experience, how IoT has been included in some of the authoring tools. It will also discuss design guidelines for game authoring tools based on the existing tools and research. Finally, it will discuss game authoring tools specially for cultural games.

2.9.1 Design guidelines for game authoring tools

When discussing design guidelines for game authoring tools, it is important to also note the guidelines for the games those tools will produce. This research will develop a tool that creates serious cultural games that are in first person and will allow the users to create their own levels and quests. Therefore, understanding what design guidelines should be followed for educational games is important to make sure the tool produces games that follow those guidelines.

A framework suggested by (Aleven, et al., 2010) focuses on three main components:

1) Learning objectives: What the game will eventually teach the user, what impact will it have on the user and how will these objectives be taught to the user.
2) MDA: Mechanics, Dynamics and Aesthetics (MDA) of a game are the multiple components that goes under each of these terms but most importantly it describes the entire feel of the game, what the user will feel, experience, and basically do in the game and how it will be done. This is very important because if an educational

game includes a lot of violence mechanics in it then it might frighten the little kids playing it instead of educating them.

3) Instructional principles: This component focuses on research-based principles which already exist which provide guidelines to how the instructions in the game should be to guide the user through the learning process like a teacher. In this research, the tool includes a virtual assistant, story archives, and basic control instructions.

Some examples of instructional principles are the Cognitive Tutor principles which suggest giving immediate feedback after an error and based on that the tool might have the feature of showing immediate errors when the players give wrong answers to questions in the games (Anderson, et al., 1995). This could be a feature implemented by default so that the user designing the game using the tool would not have to worry about knowing these instructional principles. In addition to that, they are the Multi-Media Principles which provides guidelines on how to create educative multimedia components which might include visuals or audio which could be useful in designing the features that will allow users to include the learning content in their games (Mayer & Moreno, 2003).

Four important factors that can facilitate cultural learning in virtual heritage environment have been outlined in this research which are information design, information presentation, navigation mechanism, and environment setting (Ibrahim, et al., 2015). Schofield (2019) identified three key approaches in heritage research which are Cultural Heritage, Plural Heritage and Future Heritage and explored a Plural Heritage approach to a UNESCO World Heritage Site with design interventions along with contemporary methods for heritage education and it demonstrates the essentiality of heritage learning carried out in an extensive HCI project. Nazrita (2015) points out the necessity of reducing the cognitive load of the users by incorporating cultural information when the users would explore the virtual environment to add value to their understanding. Two types of design elements were included in this proposed conceptual framework which were basic elements that were essential for cultural learning and extended elements for enhancing user experience and the framework evaluation of the proposed two design elements showed that it increased user awareness towards preserving heritage (Ibrahim & Ali, 2018). These studies clearly show that without including cultural information either in text-based or model-based in virtual environment, cultural education cannot be carried out appropriately (Ibrahim, et al., 2015; Schofield, et al., 2019; Ibrahim & Ali, 2018).

In the context of CH, games have been used to increase user engagement and introduce an active state of learning, however current game designs or evaluation methods do not consider the differences in visual information processing of the gamers. A study was carried out with three heritage games on three separate user studies which were 127 participants over a six-month period to understand if there was a deficiency in understanding due to design considerations (Raptis, et al., 2019). The evaluation revealed that sometimes the decision of game designers showed unintentional bias towards users with specific cognitive characteristics resulting in inappropriate visual information processing (Raptis, et al., 2019). It is important to deliver personalized cultural heritage activities tailored to the context and to consider the difference in cognitive abilities of the users.

Although serious games have provided a new method of learning with an increased edutainment value, but this teaching approach still is deficient of proper tools and methodologies specially for the teachers or domain experts such as museum managers. To address that issue, this research proposed an authoring framework called Sandbox Serious Game that depends on generalized text-based learning theory, specifically suited for cultural heritage edutainment applications from designing phase to implementation (Bellotti, et al., 2013). It appeared that games well suited for CH knowledge acquisition and retention, requires a well-designed game that includes appropriate content with proper connections, graphic appeal, usability aspect and integration of cross-disciplinary methods such as history teachers or elders to create instruction goals and design foci (Bellotti, et al., 2013; Huang & Huang, 2013). Serious game "Papakwaqa" for Taiwanese history and life of indigenous people, developed following Huang's framework showed positive outcome in learning motivation for children (Huang & Huang, 2013). Two samples of graphical exploration game method can be seen in Figure 2.5 and 2.6.

Figure 2.5 Sample of two PoIs (Palazzo Rosso and Palazzo Bianco) (Bellotti, et al., 2013)

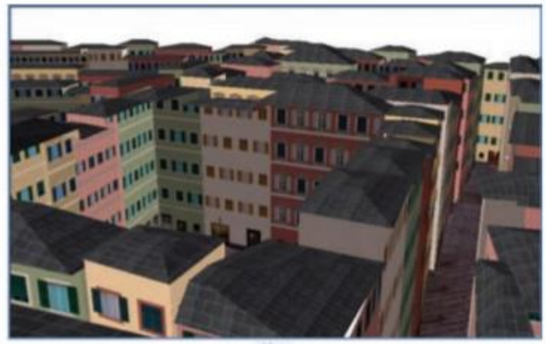

Figure 2.6 Sample of an area in city of Genoa (Bellotti, et al., 2013)

Serious games pose a more difficult challenge than video games as it requires to be relevant for education as well as have entertainment value with less cognitive load. Moreover, serious games focusing on cultural heritage need extra effort for creating the necessary immersive factor and collaboration among players. A design framework for CH serious games named FRACH was suggested in this study which was meant for designing, developing, and evaluating immersive as well as collaborative serious games for cultural heritage (Andreoli, et al., 2017). The competency of the framework FRACH was tested by implementing a part of a serious game called *HippocraticaCivitasGame* where the players get to visit two historical sites in city of Salerno, Italy and solve given puzzles. Andreoli (2017) mentioned the results showed better knowledge acquisition, increased enjoyment and finally positive feedback for using serious games for CH following proper design guidelines.

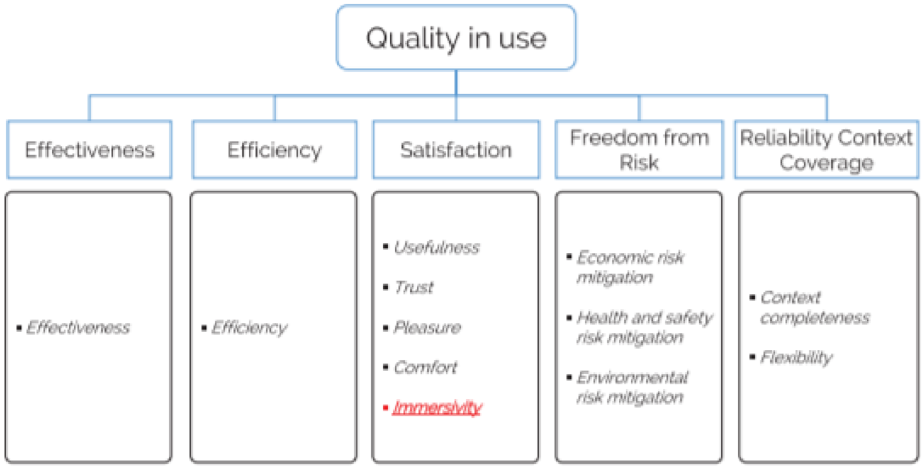

Figure 2.7 Quality in use model extended with the immersivity aspect (Andreoli, et al., 2017; ISO/IEC-25010, 2011)

Figure 2.8 Product Quality model (ISO/IEC-25010, 2011; Andreoli, et al., 2017)

The ISO/IEC 25010 (2011) is essentially a quality standard for analysis, design artifacts and software and it has two models which are the quality in use model that considers the software while it is used (Figure 2.7), and the product quality model that considers the software's static properties (Figure 2.8). ISO/IEC 25010 has been extended by much research in various fields, modifying or putting additional quality sub-characteristics as in Figure 2.7 is immersivity. A product quality model for SGs was proposed, which had been adapted from the ISO/IEC 25010 (García-Mundo, et al., 2015).

While the tool in this research was not be designed solely on instructional principles, they definitely affected some of the design choices. The tool also included participatory design feedback which was invaluable to the design of the final product. Moreover, the tool was inspired by Role Playing Games that have been successful in narrating historical stories and have been massively played and impacted thousands of players out there like the world-renowned Assassin's Creed and Kingdom Come: Deliverance.

To fully understand the effective use of the maker-based construction process, there should be more studies offering design guidelines for future platforms. A framework for designing serious games suggested by Aleven et al. (2010) focuses on three main components: (1) learning objectives, (2) Mechanics, Dynamics, and Aesthetics (MDA), and (3) instructional principles. Learning objectives focus on what the game will eventually teach, what impact it will have and how these objectives will be taught to the user. The MDA of a game describes the entire feel of the game, such as what the user will feel, experience, and do in the game and how. Instructional principles apply existing research-based principles to provide instructions in the game to guide the user through the learning process like a teacher.

The authoring framework Sandbox Serious Game by (Bellotti, et al., 2013), however, is limited to the creation of tasks which can be added as focal points on an existing 3D environment without letting the user design the 3D environment. Moreover, the task tool is intended to be used only by CH experts and the interaction is only limited to mouse-clicks. Game development tools are required to target which area they are focusing on to be able to cater to those specific users, and such game authoring tools are important in designing and developing video games (O'Donnell, 2013). It stands to reason that when the game authoring tool is catering to users for cultural story sharing, specific design considerations need to be gathered and integrated into the authoring tool so important aspects such as the historical facts, geographical locations, and artefacts for well-known cultures are available in the game authoring tool. The way the users are allowed to interact with the tool have an impact on the interventions for developing a game authoring tool (O'Donnell, 2013).

A generic platform such as SCRATCH is only meant for 2D and will not provide the immersion aspect a 3D game can provide including not having the requirements of it to be a proper cultural game authoring tool. Similarly, Minecraft may be 3D and used to make games, but it does not have realistic graphics and focuses on using pixelated 3D models which defeats the purpose of immersive aspect besides not catering to cultural video game production. Unity 3D, the game software, depicted as 'voodoo software' by game developers and acts as a boundary object, but using Unity 3D requires rigorous coding knowledge and can be used by developers only (Whitson, 2017). For non-experts to be able to use Unity 3D to make serious 3D games is extremely hard and the cultural archive of historical facts, location and such are not readily available. Hence, a serious 3D maker-based cultural game authoring tool would focus on allowing the non-typical users such as non-game developers of all ages to be able to share cultural story and would consist of historical facts, locations, artefacts, and even myths. Ibrahim & Ali (2018) proposed a conceptual framework that guides the design of a virtual environment to consist of four essential elements: information design, information presentation, navigation mechanism, and environment setting. Schofield (2019) identified three key domains in heritage research which are Cultural Heritage, Plural Heritage, and Future Heritage, and explores a Plural Heritage approach to a UNESCO World Heritage Site with design interventions along with contemporary methods for heritage education.

Ibrahim et al. (2015) pointed out the necessity of reducing the cognitive load of users by incorporating cultural information when users are exploring the virtual environment to add value to their understanding. Although game developers have been using commercial game engines to create serious games, there is a need to have an instructional design to create a constructionist environment. Games built with the concept of a constructionist environment incorporate conceptual thinking and develop problem-solving skills, hence Vahldick et al. (2016) discussed the implementation of a serious game engine based on the basic elements that are essential for cultural learning as well as extended elements for enhancing user experience. The activist-casual framework discusses how to integrate both serious game design and casual game design and create impactful games while avoiding the negativity of the commercial casual game industry (King, 2021).

Character designs and inclusion of various cultural aspects in a character should be considered in a game authoring tool and the characters have a significant way of relaying information related to cultural clothing, hairstyles, and more. Pozo (2018) indicates the importance of linking empathy with appropriate character design as such practices have an impact for participatory design and inclusion. Normalized value practices and diversity conscious character designs should be formulated where it is not specifically following a certain category e.g., excessively masculine and manages to encompass the diversity in population (Tompkins & Martins, 2021).

Chia (2022) discussed game engines such as Unity and Unreal as platform tools for designing simulated 3D environments within a game and beyond a game. However, game engines such as Unity and Unreal are advanced and require game developers to be able to code a game and for a culture specific topic, a game developer would have to design the game a particular way e.g., Assassin's Creed Series. Hence, with such technologies, now the focus should be on allowing any one expert, and non-experts alike to be able to use a platform for any cultural heritage sharing with integrated settings. Videogames have been known to generate cultural meaning, but the way video games are developed are understudied, which is why Keogh (2021) conduct a study with interviews to use video game authoring tools as a cultural producer and it demonstrates inclination to the aforementioned purpose. However, for such an advanced tool catering specifically to cultural heritage, research needs to be carried out about gathering design guidelines and whether more interactive technologies should be integrated (Abdulrazic, et al., 2022).

More recently a new authoring tool with the name of AdLer was designed to offer lecturers a way to design and generate virtual 3D learning environments where the students can interact with various learning content and it is all designed according to the principles of game-based learning (Klopp, et al., 2023). Similarly, not all game authoring tools are digital in nature, as seen in (Cai, 2023) who developed a physical toolkit that allows children aged 3-6 to create immersive narratives based on their emotions.

2.9.2 Artificial Intelligence (AI) in game authoring tools

When we talk about AI, we often think of virtual assistants, facial recognition, and similar technologies (Ippolito, et al., 2022). AI as a virtual assistant in serious game authoring tools enhances the development process by providing real-time support and recommendations (Anantrasirichai & Bull, 2022). These AI assistants can help designers by suggesting improvements, automating repetitive tasks, and offering insights based on data analysis. They facilitate the creation of more effective and personalized educational games by ensuring that the content and mechanics align with learning objectives and user needs. This integration of AI helps streamline the authoring process, making it more efficient and responsive to the requirements of personalized learning approaches. AI shows promise in various applications such as content creation, information analysis, and post-production workflows, its potential as a standalone creator remains modest, particularly in domains with fewer constraints. The focus should thus be on augmenting human creativity rather than replacing it, maximizing the benefits derived from AI in the creative process (Anantrasirichai & Bull, 2022).

AI has also been integrated into various software applications in the 21st century, including game authoring tools. This integration is part of a broader trend where cultural heritage has entered a new digital era. People have become active participants and recipients of actions that can ensure the sustainability of cultural heritage. This research simply proposed a social recommender architecture for cultural artwork sustainability as people are active elements which discovers and exploits social similarities between users and groups users together based on their preference in artworks (Hong, et al., 2017).

Complex systems instead of simple systems are being preferred now in conveying important information such as Multimedia collections, Sensor Networks via sophisticated applications to complement user experience in learning about Cultural Heritage. Amato (2017) developed SCRABS on top of Big Data technological stack during Cultural Heritage Information Systems national project of Italy which is a smart context-aware browsing assistant for cultural environments. SCRABS followed the technical features of being able to gather information from heterogenous sources such as Sensor Networks, to provide appropriate and personalized data based on user preference and perform smart services such as recommendations to help browse cultural multimedia information and information retrieval to identify information of interest and data analytics of a given PoI (Amato, et al., 2017; Francesco Colace, et al., 2015; Chen & Zhang, 2014).

Unity is one of the world's most used game engines, with millions of users and plenty of high-end games being developed using the engine. Asides from all the professional rendering features and the advanced functionalities that make Unity stand out from the other game authoring tools, Artificial Intelligence features is one of the things that many game developers really like about Unity. Without having the need of being an AI expert, game developers can implement some very complex AI behaviour into their games, ranging from AI characters moving autonomously in the game, to random character behaviour. Unity has a good community support and tools like the Machine Learning Agents that allows game developers to get a head start in including AI behaviour in their games.

Similarly, the Unreal Engine which is Unity's main competitor comes packed with amazing AI features to help game developers include amazing AI features in their games. Unreal Engine include Behavior Trees which is a tool that could be used to design and create AI behavior to your game components without writing any code or having any knowledge of common AI and ML languages like Python or R. With the recent boom in AI in every field, new services like Ludo have emerged that assist users in designing games using the power or AI. The productivity of using AI tools could certainly help in quickly prototyping ideas and saving time doing redundant tasks. AI has become deeply ingrained in everyday life, extending far beyond the mobile phones that almost everyone carries. Today, voice assistants and smart speakers are mainly used to play music, control lights, or provide weather forecasts. AI chatbots are getting smarter due to advancements in neural networks, enabling them to chat, answer questions, write scripts, scientific papers, or even program code (Shafeeg, et al., 2023). Farcana has combined the functionality of a GPT chatbot with a voice assistant, offering players a novel approach to learning game mechanics and managing accounts. This innovation not only highlights Farcana's competitive edge but also significantly contributes to the advancement of AI in the digital society.

Anjum et al. (2024) investigates the role of large language models (LLMs) as creative collaborators and "muses" in game design, inspired by artistic exercises using amorphous ink splotches for creative inspiration. It aims to assess whether AI assistance can enhance, hinder, or offer a distinct quality to games compared to human designers' creative outputs. Additionally, the paper supports AI's use in personalized learning and as an assistant in game authoring tools, showcasing its potential to transform and streamline creative processes in game development (Anjum, et al., 2024). This paper explores using AI to generate quest descriptions for RPGs to meet the increasing demand for rich game content (Värtinen, et al., 2024). Supporting ChatGPT as an assistant in this context showcases the potential for AI to transform user experiences and streamline interactions across various platforms.

This systematic literature review underscores the significant impact and widespread discussion surrounding ChatGPT as a writing assistant in academia (Imran & Almusharraf, 2023). It highlights the diverse opinions and scenarios associated with utilizing AI, particularly ChatGPT, in educational contexts, including academic writing. Given its emergence as a prominent tool since its release, understanding its role as both an aid and facilitator in the education process is crucial. Drawing from this, integrating ChatGPT into serious game authoring tools offers an opportunity to enhance the development process by providing real-time support and recommendations for creating personalized and engaging educational experiences. This underscores the importance of leveraging ChatGPT's capabilities to streamline the creation of high-quality serious games while also ensuring alignment with educational goals. It's crucial to note that while ChatGPT assists in the development process, individuals will still retain control over their storytelling and game creation. ChatGPT simply serves as a helpful tool, augmenting human creativity rather than replacing it, and allowing developers to craft personalized and engaging educational experiences (Imran & Almusharraf, 2023; Anantrasirichai & Bull, 2022).

2.9.3 IoT in game authoring tools

IoT can enhance serious game authoring tools by integrating real-time data from physical environments, creating dynamic and responsive learning scenarios (Huang, et al., 2021). This technology enables immersive and interactive experiences, significantly improving experiential learning. When it comes to including IoT in game authoring tools, there has been a clear lack. Mostly, because it is a new technology and very few have taken the chance to go and develop tools with IoT features. However, we have seen some promising tools that included IoT in its features. While not particularly a game authoring tool, The Tiles IoT Inventor Toolkit designed by (Mavroudi, et al., 2018) consists of cards which contains descriptions of IoT components that helps people design and prototype IoT solutions quickly and efficiently. It has to be noted that this is just a prototyping kit and does not actually offer a complete product.

Minecraft Education is an application that is primarily intended as a way of using Minecraft to create educational games. Minecraft is a phenomenon that started in 2009 and has spread globally ever since. It is a block-based first-person game where the players get to build buildings, landscapes, etc. using their own imagination while also collecting raw materials and crafting equipment. The game has been open to "modding" which is a term used when a game allows its community players to modify the source code to add their own custom edits to the game. The game has ever since seen an increase in popularity with hundreds of new game modes being created by the community. Minecraft Education was created to allow teachers and students alike to create Minecraft educational games, which somehow places it under the category of a game authoring tool. Using the extension MCreator Link the users can connect IoT boards like the Arduino or a Raspberry Pi and use Scratch-like programming visual blocks to code the logic of the sensors.

Recently in 2019, Raspberry Pi and Scratch announced the new extensions that allow the users to use the Raspberry Pi's sensors and SENSE HAT through the built-in extensions in Scratch 3 (O'Hanlon, 2019). These extensions allow the users to quickly use the sensors that they connected on the Raspberry Pi's General-Purpose Input/Output (GPIO) pins, like motion sensor, touch sensor, while also being able to connect a more sophisticated device like the SENSE HAT using three unique extensions. Notably, however, Scratch must be running on the Raspberry Pi itself and not through a computer which limits the processing power and hinders the user experience.

2.9.4 Exploring Child-Computer Interaction and Serious Game Design

Research study by Iversen and Brodersen (2008) addresses the evolving field of child–computer interaction, highlighting the increasing integration of information technology into children's daily activities. Departing from the traditional notion of treating children as "cognitive incomplete" compared to adults in design processes, the study advocates for considering children as active participants in meaningful communities of practices, challenging the idea that they should be involved in design as a distinct discipline. Iversen and Brodersen (2008) introduce the BRIDGE method, presenting a palette of design techniques that underscore involving children as experts in their everyday lives, emphasizing the importance of their contribution in shaping future IT designed for children. Khaled and Vasalou (2014) critically examines the application of Participatory Design (PD) in serious game design, a domain where user involvement has traditionally been limited. The authors share their experiences using PD in the design process of a serious game, highlighting challenges encountered in applying existing PD methods like brainstorming and storyboarding. The paper contributes to the evolving landscape of participatory approaches in serious game design, acknowledging the changing roles of designers and users in the collaborative design process (Khaled & Vasalou, 2014). This study investigates the efficacy of sensitizing techniques in assisting children, aged 7 to 9, to design a serious game for a surrogate population, focusing on life in rural China (Sim, et al., 2017). The findings underscore the need for further exploration into children's contributions to serious game development, particularly in understanding their role in addressing cultural nuances for diverse populations (Sim, et al., 2017). Through an extensive review of the literature, the study identifies positive experiences in the development and use of Serious Games for children (Valenza, et al., 2019). The guidelines serve as valuable recommendations for designers and developers of SG for children, offering insights to ensure that the final products align more closely with children's preferences.

In this study by Vieira et al. (2022), the authors address the pervasive presence of electronic devices in children's lives and advocate for a child-centered design approach in the development of serious games on sustainability. The research incorporates participatory design, prototyping, and evaluation to understand children's behavior and gather feedback on requested tasks. Preliminary findings suggest that children actively engage with prototypes, providing valuable feedback and innovative ideas to enhance the serious game's appeal and accessibility for their peers (Vieira, et al., 2022). This paper challenges the prevailing trend in academic literature that tends to underreport failures in the field of Child-Computer Interaction (CCI) (Rukmane, et al., 2022). The authors advocate for a paradigm shift, asserting that failures should be acknowledged as valuable learning opportunities rather than concealed setbacks. Rukmane et al. (2022) into the challenges faced in designing and conducting studies involving children, commencing with a comprehensive literature review and subsequently conducting interviews with 14 researchers in the CCI community. Through thematic analysis of the interviews, the paper identifies three key themes (unpredictability, technology designed for adults, children's goal orientation), outlines three actionable points (context, technology, and activity), and advocates for a transformative shift in perspective—moving from the notion that failures should be hidden to embracing them as opportunities for learning within the CCI research community. The academic field of Child–Computer Interaction (CCI) emerged in the 21st century alongside the rise of interactive technology and digital media targeting children. Antle and Hourcade (2022) perceiving a crucial juncture in CCI's development akin to adolescence, engage in reflective discussions on broader responsibilities, values shaping childhood perceptions, and the evolving role of interactive technology. This contribution aims to stimulate dialogue, offering alternative visions for the future and emphasizing the urgency to explore diverse perspectives for the next 20 years of CCI research.

2.9.5 Game authoring platforms for serious 3D cultural games

While IoT integration in game authoring tools is limited, promising initiatives like the Tiles IoT Inventor Toolkit (Mavroudi, et al., 2018) facilitate quick prototyping of IoT solutions. Tools such as Scratch 3 extensions for Raspberry Pi sensors and Minecraft Education's IoT board connections through extensions like MCreator Link demonstrate the potential of integrating technology in game development (Mojang, 2024). Popular game engines like Unity and Unreal Engine offer sophisticated AI tools, such as Unity's Machine Learning

Agents tool and Unreal Engine's behavior trees, which enable complex AI behavior design without expert knowledge.

Serious games, aimed at education and learning rather than entertainment, are increasingly prominent in literature and applied across diverse fields like education, healthcare, and physical training. IoT can enhance these games by providing immersive and interactive experiences, although deploying serious games in an IoT environment introduces new challenges. This paper surveys IoT-enabled serious games, examining their development, current state, and the challenges that remain to be addressed (Hong, et al., 2017). Amato (2017) presents SCRABS that collects data from diverse sources, and tailors personalized information and recommendations for users navigating cultural multimedia content.

Minecraft Education, a sandbox game, allows students to explore virtually infinite 3D worlds, promoting cooperation and problem-solving (West & Bleiberg, 2013). However, it lacks support for situated cognition due to its unrealistic environments and limitations in rendering specific historical architectures. Realistic 3D environments in cultural heritage games can enhance engagement and learning by allowing players to interact with accurately reconstructed objects and settings. Cultural heritage games can benefit from realistic reconstructions of 3D objects or buildings of interest, allowing players to manipulate, rotate, enlarge precious objects with no risk of damage. The decision between utilizing 2D or 3D settings in a serious game is contingent upon various factors, including the target audience and the intended market. As evident from the literature, the necessity for a 3D setting is not universal, particularly in trivia and standard puzzle games. Conversely, a significant proportion of recent adventure games opt for 3D environments. This preference aligns with games involving exploration or navigation actions, such as historical reconstructions and virtual tourism, which benefit from the immersive nature of 3D settings, enhancing the learning process through situated cognition. Realistic 3D environments enable players to interact with objects within their contextual environment, facilitating deeper engagement and understanding, particularly in historical awareness games. For example, comprehension of historical events like the Battle of Thermopylae can be enriched by navigating and interacting with the surrounding terrain (Christopoulos, et al., 2011). Larson (2020) reviews the use of gamification and serious games in the workplace, exploring how game design mechanisms can make real-world activities more engaging by leveraging the psychological predisposition to gaming. Serious games, designed with purposes beyond entertainment, positively influence cognitive, emotional, and social domains, thereby increasing learner motivation and engagement. Within gamified environments, individuals often willingly engage in repetitive tasks and persist despite failures, which can be beneficial for workforce recruitment, retention, program adoption, and performance improvement. Additionally, this paper discusses the importance of game authoring tools, which can facilitate the creation and customization of gamified experiences tailored to specific workplace needs, thereby addressing some of the implementation challenges by offering flexible and user-friendly solutions (Larson, 2020). Open-ended gameplay, commonly referred to as "sandbox" gameplay, appears most suited for 3D environments in serious games, as it allows players to construct knowledge structures relevant to the game's themes. Furthermore, serious games focused on virtual museums or tourism can leverage faithful 3D reconstructions of objects or architectural landmarks, enhancing the informative and engaging nature of the experience.

Research shows that first-person 3D games provide more immersion compared to third-person games and that 3D settings improve performance in educational contexts (Denisova & Cairns, 2015; Chávez, et al., 2020). A comparative study on healthcare education comparing 2D, 3D, and VR serious games concluded that performance was better using 3D games compared to 2D (Chávez, et al., 2020). Sanzana et al. (2023) explores serious first-person 3D games and shows how the students managed to learn two different science subjects in an immersive way using a first-person 3D serious game. Drosos et al. (2018) shows how a 3D first-person serious cultural game provided good learning outcomes and high immersion rate among the participants, further solidifying the concept that 3D first-person serious cultural games are a good tool to aid in cultural heritage education.

For cultural heritage, 3D environments are particularly beneficial, offering immersive experiences that help preserve and teach cultural knowledge (Mortara & Catalona, 2018). Fairuz and Ng (2018) used a Malaysian folklore game design as a way to preserve culture, while it is not an authoring tool it does show how culture could be preserved if the tool that designed the game integrated the culture while designing. An authoring tool that allows users to create cultural games without coding, incorporating professional 3D assets and AI features, could significantly enhance the development of serious cultural games.

In terms of interaction paradigms, there is a discernible trend towards naturalistic interactions, such as tactile interfaces, although traditional mouse and keyboard setups still enjoy customer satisfaction (Huang & Ng, 2021). Emerging technologies like gesture recognition and multi-modal interactions, facilitated by affordable devices like IoT, show promise in enhancing usability and motivation through more immersive and embodied interactions (Ahmad, et al., 2022).

The serious game model developed by Bellotti (2013) describes some of the common templates that are effective with serious games, SandBox Serious Games concept by Squire (2008) and Bellotti (2010) is discussed and how designing a proper cognitive-supporting structure is important. Minigames and the inclusion of task templates are also discussed highlighting the relevance and importance of these concepts in serious cultural games.

The educational potential of storytelling is well-established, with recent interest in interactive digital storytelling for its capacity to empower users in educational contexts (Hodhod, et al., 2011). Molnar and Kostkova (2016) introduces Edu-Interact, a game authoring tool designed specifically creating interactive digital storytelling-based games without the need for any programming skills which provides a summative assessment to the teachers and provides feedback to the students, in the form of a score. Despite providing feedback on the student's performance, the tool only creates 2D digital story-telling based games and is not as immersive as the proposed 3D immersive game authoring tool in this research. Naul and Liu (2019) reviews the role of narrative in immersive learning environments, such as digital educational games and simulations, and synthesizes research on successful story features within these contexts. The findings highlight four effective characteristics of game narratives: distributed narrative, intrinsically integrated fantasies, empathetic characters and virtual agents, and adaptiveness or responsivity. Immersive learning environments and storytelling are crucial because they significantly enhance the educational experience by making it more engaging and meaningful. Narratives provide context and emotional connections that help students better understand and retain information. They create a sense of immersion, allowing learners to feel part of the story, which increases motivation and engagement. The use of empathetic characters and adaptive storylines can tailor the learning experience to individual needs, further enhancing its effectiveness. Overall, storytelling in educational games and simulations makes learning more interactive, relatable, and impactful.

Educational video games have a positive impact on students' motivation and learning outcomes, but a lack of accessible authoring tools limits widespread adoption (Gordillo, et al., 2021). Existing research underscores the positive impact of educational video games on students’ motivation and learning outcomes across diverse educational levels and disciplines (Gordillo, et al., 2021). However, the widespread adoption of game-based learning is hindered by a shortage of accessible authoring tools that empower educators to seamlessly create and customize educational video games to suit their specific pedagogical needs. To address this gap, Gordillo et al. (2021) contributes by introducing SGAME, a teacher-oriented authoring tool for educational games. Through an examination of teachers' perceptions, this research aims to contribute valuable insights into the utility of such tools for facilitating effective game-based learning experiences in educational settings (Gordillo, et al., 2021). While it is true, that most game authoring tools could be used for cultural games, it would be a complex task and beneficial design choices for serious cultural games would have to be done by the game designer. There are existing game authoring tools that do not require the user to know how to code, like Scratch, AgentCubes, BuildBox, FlowLab. However, they are mostly focused on 2D games, which are best for teaching kids how to code. Cultural heritage would benefit from immersive 3D environments, and to create those you require more sophisticated game engines like Unity or Unreal Engine, and programming expertise. Having an authoring tool that allows users to create cultural games easily, without coding, having a range of professional 3D assets of cultural characters, buildings, and the inclusion of AI features to help the user design the level through a virtual assistant while providing tips for best design practices for cultural serious games could fill that gap need to create serious cultural games easily. At the same time, providing specific features to help create treasure hunt themed game easily, character conversations and first-person games out of the box would help keep the serious games developed stay on track of proven successful cultural games based on research.

Finally, the collaboration between educators and computer scientists in serious game development is often hindered by varying levels of technical expertise. Laurent et al. (2022) address this by establishing design principles for authoring tools that balance power and usability, enabling the creation of diverse serious games by multidisciplinary teams. These advancements highlight the importance of tailored authoring tools in enhancing the educational potential of serious games.

2.10 Summary

The landscape of Human-Computer Interaction (HCI) within cultural applications and serious games has witnessed significant evolution. This literature review explores the historical developments, methodological applications, and theoretical foundations within HCI, focusing on its integration with cultural themes in venues such as museums. Concurrently, it delves into the realm of serious games, elucidating their inherent benefits and the diverse ways in which they have been assimilated into both educational and cultural contexts. Importantly, this review identifies a notable gap pertaining to the development of a serious 3D cultural game authoring tool, representing a technical focus that demands further exploration. As backed up by previous literature in Section 2.9, first-person 3D serious games can provide good outcomes in terms of learning gains, immersion, and usability. They have also proven to be useful in cultural heritage scenarios, which gives enough motivation to design this tool in a way that allows for the creation of first-person 3D serious cultural games.

The integration of HCI within cultural applications, particularly museums, has marked a transformative juncture. Methodological approaches have varied, encompassing interactive exhibits, virtual reality (VR), and augmented reality (AR). For instance, interactive exhibits have allowed users to engage with cultural artifacts through touchscreens and gesture-based interfaces, providing immersive experiences (Marshall, et al., 2016). VR and AR technologies have further augmented visitor engagement, offering simulated environments and enhanced storytelling (Not & Petrelli, 2019).

Serious games, designed with a primary focus on educational or cultural objectives, have become pivotal tools in fostering immersive and impactful learning experiences (Sanzana, et al., 2023; Sanzana, et al., 2024). These games transcend traditional educational methodologies by incorporating interactive narratives and gameplay elements. Examples include educational games designed to teach historical events, cultural practices, or language acquisition (2018). However, a critical exploration reveals a dearth of tools specifically tailored for the creation of serious 3D cultural games, pointing to a significant gap in the existing literature.

Existing literature reviews various design guidelines for serious games, emphasizing factors such as user engagement, pedagogical effectiveness, and narrative cohesion (Quah & Ng, 2021; DaCosta & Kinsell, 2023). Moreover, the integration of Artificial Intelligence (AI) in game engines and the advent of the Internet of Things (IoT) are emerging as key components in enhancing the capabilities of serious games (Mavroudi, et al., 2018). The potential of AI lies in personalized learning experiences and adaptive gameplay, while IoT can facilitate real-world interactions within the gaming environment (Amato, et al., 2017; Francesco Colace, et al., 2015; Chen & Zhang, 2014).. However, the literature indicates a limited exploration of the combined potential of these technologies in the context of serious 3D cultural games.

This research is grounded in the theoretical framework of the maker pedagogy, constructionism and constructivism, and the multiliteracies pedagogy, recognizing the influence these learning theories have on the development of new educational tools. The identified knowledge gap centers on the absence of a dedicated serious 3D cultural game authoring tool that leverages modern technology for its main mechanics. The learning theories focus on learner-centered approaches, experiential learning and personalized learning as key elements of their frameworks.

The primary objective of this research is to develop an innovative educational tailored for cultural heritage learning that implements the key points derived from the learning theories researched in this literature review section. By designing the tool around these concepts, the tool can provide an immersive and innovative learning tool that focuses on the learner, allows them to learn by doing and provides a personalized learning experience for every individual. The tool will focus on allowing the learners to create 3D serious cultural games and will include new technology in the form of ChatGPT as an AI assistant and RFID card input as an element of IoT technology to improve the user experience and improve its accessibility.

To illustrate the practical application and impact of the serious 3D cultural game authoring tool, the research will include in-depth case studies which would showcase diverse educational settings, demonstrating how the tool enhances cultural learning experiences through immersive and interactive gameplay.Drawing insights from literature reviews, surveys, and interviews, the research will culminate in the formulation of a set of design guidelines. These guidelines would serve as a valuable resource for future researchers and developers seeking to design and implement serious 3D cultural game authoring tools. In summary, this literature review sets the stage for a focused exploration of a serious 3D cultural game authoring tool, highlighting its technical emphasis and potential contributions to educational and cultural domains. The subsequent sections of the research would delve into case studies and empirical analyses, providing a comprehensive understanding of the tool's development, implementation, and impact.

Chapter 3 Methodology

3.1 Introduction

This section explains the methodologies used in this research in detail. It demonstrates all the different stages that were required to complete this research and the workflow between those different stages. In addition to that, it explains the features of the proposed tool, the software and hardware used accompanied by a use case diagram and a graphical storyboard to help explain the system better.

The key stages of this research are discussed briefly below:

1. **Reviewing learning theories, serious games literature and getting initial feedback:** Initially before starting to design and develop the tool the theoretical framework that will guide the flow of the features of the tool needed to be researched. Considering the educational aspect of the tool learning theories were researched and especially the one relevant to the nature of the tool. The maker pedagogy and the multiliteracies pedagogy were the most relevant to the research as they promote learner-centered approaches, experiential learning or learning by doing and the personalized learning aspects. They are also learning theories that have a lot of potential for integrating technological solutions.

   To better understand if the inclusion of IoT in a game making tool is feasible or not a short HCI competition was held in the University of Nottingham Malaysia with undergraduate participants who were tasked with using the Raspberry Pi 3 with the known 2D game making tool SCRATCH. This trial proved useful as it gave insights into how participants perceive the technology and how a trial flow could work if Raspberry Pi and sensors were included. This was a useful step to understand if integrating IoT in any form in the proposed tool would be a good idea.

   Moreover, literature review on design considerations in serious games and especially serious cultural games was crucial to develop an initial understanding of important design elements that make those games work. Based on research on learning theories and serious game design research an initial design guideline was developed on which to base the initial prototype of the tool. Interviews with experts, teachers, and education students provided the first initial feedback on the idea of the tool and its current state. It also provided a clearer vision for the next step of the tool to make sure it aligns with the learning theories chosen while still providing a pleasant user experience.

2. **Designing and developing the tool:** After initial feedback on the tool from the interviews the development of the tool progressed further to include the features that allow users to create their own game logic. Paired with the level designing features implemented initially before the interviews, the tool would now allow users to create complete games. The tool got evaluated in a user trial involving school students and was focused on the user experience when using the tool. Since the tool allows the users to design their own games and play existing games designed with the tool it was important to evaluate the user experience in both aspects. Feedback from this trial was important for the final development phase of the tool. Throughout the development of this tool, it was important that the design and development processes were backed by learning theories, research review, and feedback from participants to make sure that the developed tool benefits and adds value to the research body.

3. **Evaluating the impact of using the finalized tool on cultural heritage:** The final main step of this research is to evaluate the finalized tool in a user trial and test out the two main functionalities that it set out to achieve. This included a trial where students get to design serious cultural games about the Kristang culture and compare that approach with a control group using 2D storyboards, and also playing a demo serious cultural game about the Kristang culture and measuring the learning impact compared to a control group who learned using presentation slides. The initial design guidelines that were created using the learning theories, research review and feedback from interviews has been updated after the second trial and finally updated after the final trial to create a robust set of design guidelines for

future researchers and developers who might be interested in creating a serious 3D cultural game making tool.

3.2 Research Framework

The main research framework of this research is based on the learning theories that drive the flow of this research. Both the maker pedagogy and the multiliteracies pedagogy were essential in the development of the idea of this tool. There are three main aspects of those pedagogies that were crucial to the research and integrated into the main features of the tool. Those aspects are the following:

1) The tool will follow a learner-centered approach, based on the established framework of the maker pedagogy, and seen in other research discussed in Section 2.3.1. This means that the learning journey focuses on the learner more and gives them control over how they learn. This was established in the tool by allowing the user the freedom to roam the design space and create their own games to teach others.
2) The tool will focus on experiential learning, also known as learning by doing which is one of the most immersive and effective ways of learning. This method is a key point in the maker pedagogy and one of its main cornerstones and previous research discusses approaches with that method in Section 2.3.2. The tool follows in the same path by allowing users to play and design serious games that gives them the ability to learn by doing, which is effectively done through the active playing phase.
3) The tool will offer personalized learning experiences, which is emphasized more through the use of new media like IoT and inclusion of a virtual assistant, namely ChatGPT. The multiliteracies pedagogy inspires this point and explains how different people from different backgrounds can learn in different ways and to avoid one-size-fits-all approaches and the literature backs this point as seen in Section 2.3.3. The tool realises this by offering different 3D assets and customization options when it comes to creating a game. The users are then left with a personalized learning experience that can cater to different people.

Based on these aspects the following research framework was designed depicting the main key points from the learning theories and how they were integrated into the main features of the tool. This can be seen in Fig. 3.1. There are three main hypotheses that can be deduced from the research framework, and they are labelled in the figure. The following are the hypotheses:

H1: There is a positive impact on the learning process when the users are actively involved in the process. This is both justified through existing literature in Section 2.3.1 and later also discussed in the results of the tool's user trial in Section 4.4.4, where the descriptive analysis indicated positive results from the metrics measured.

H2: Experiential learning by allowing the users to learn by playing the games is more effective than traditional learning methods. Section 2.3.2 discusses the various benefits of experiential learning but the results from the user trial in Section 4.4.5 did not provide evidence that the tool caused a significant difference in the results compared to traditional methods.

H3: Personalized learning through custom game tools and customizable options can improve the user experience. Section 2.3.3 discusses the improvement in user satisfaction and experience when personalized learning is implemented and that is also reflected in the positive user experience results in the second trial of the tool and the final trial discussed in Sections 4.3 and 4.4.

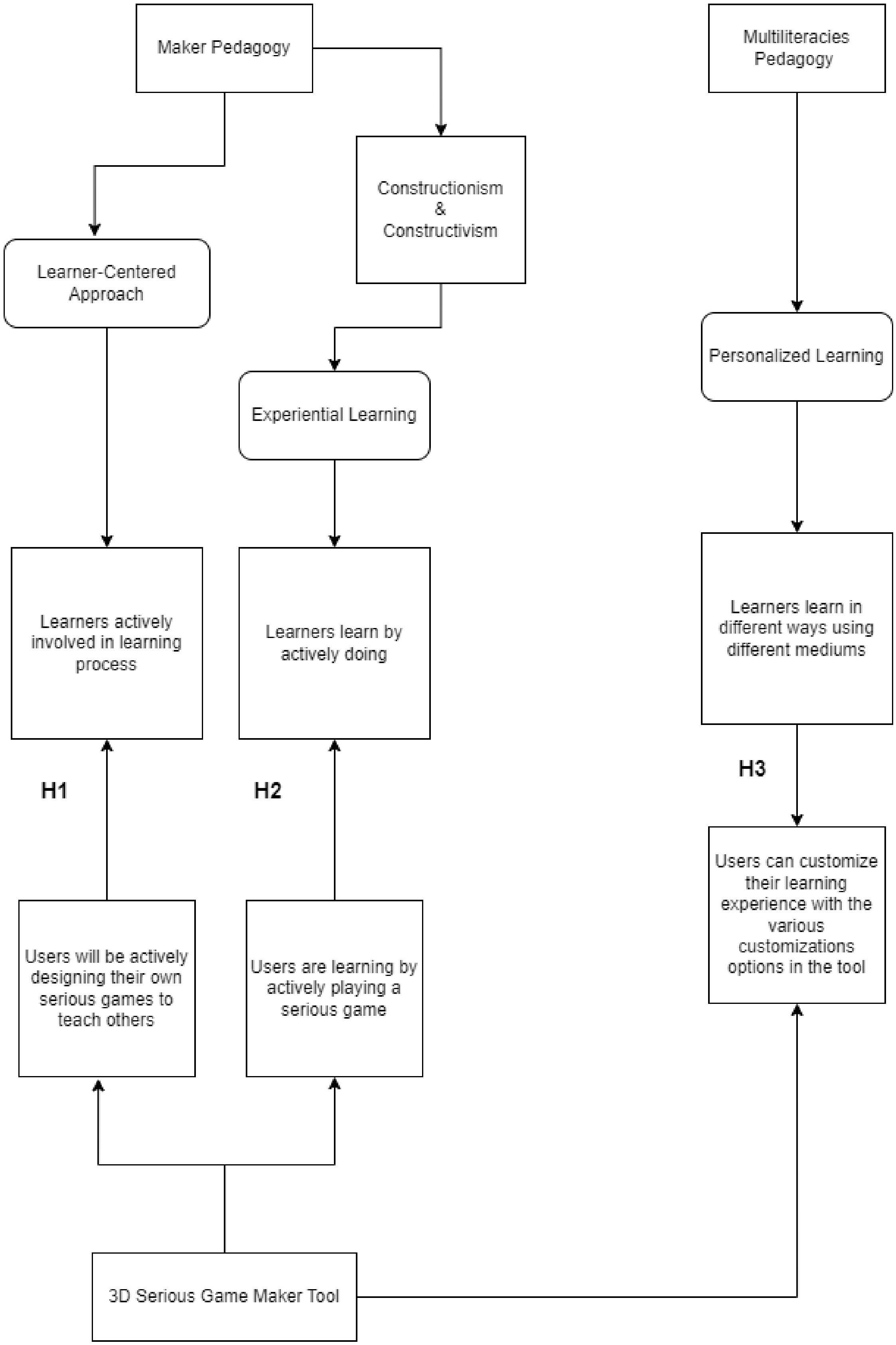
Maker Pedagogy
Multiliteracies Pedagogy
Constructionism & Constructivism
Learner-Centered Approach
Personalized Learning
Experiential Learning
Learners actively involved in learning process
Learners learn by actively doing
Learners learn in different ways using different mediums
H1
H2
H3
Users can customize their learning experience with the various customizations options in the tool
Users will be actively designing their own serious games to teach others
Users are learning by actively playing a serious game
3D Serious Game Maker Tool

Figure 3.1 Research Framework diagram

3.3 Research Workflow

After establishing the grounds and theories on which the development of this research is based, it is of vital importance to plan the workflow to achieve the final result set before. Fig. 3.2 displays in brief the workflow required to achieve the final tool and the steps and process taken along the way to achieve that.

1) The first step is to gather design requirements to determine the features of the tool and the best way to conduct trials. This was achieved using the following sub-steps.
    a. Research on learning pedagogies and find the most relevant ones that align with game-based learning and encourage the use of technology with learning.
    b. Research on serious games design guidelines and note down the most effective design choices that make serious games easier to use and teach more efficiently.
    c. Conduct a small trial to evaluate the use of Raspberry Pi 4 with SCRATCH and identify what worked well in the trial and what did not. That helps to get an initial idea about using IoT sensors in a trial.
    d. Form an initial design guideline to start designing and developing the initial prototype of the tool based on the previous steps.
2) Design the tool based on the information from the first step.
3) This step entails the actual development of the tool, and includes the steps associated with the development like getting feedback from trials and updating design guidelines, to emphasize on the participatory design approach used for the development.
    a. The development of the level designing features which would allow the users to design their own game scenes.
    b. Interviewing experts, teachers, and education students about the initial prototype and updating the design guideline with their feedback.

c. The development of the game logic features which would now allow the users to create a complete game accompanied with questlines.
d. Conducting the second trial with students and evaluating their user experience while designing and playing a game using the tool.
e. The user feedback from the trial is evaluated and analysed.
f. Based on the feedback the design guidelines are updated to incorporate that feedback.
g. The development proceeds and includes the RFID sensory input option as an IoT feature and ChatGPT is incorporated as a virtual assistant.
h. The final user trial is conducting with the Kristang culture as the target culture to teach and learn.
i. The user feedback from the trial is evaluated and analysed.
j. The design guidelines are updated for the final time to incorporate that feedback and finalized.

4) The final trial's results are analysed and cross-checked with the hypotheses. Future directions, limitations, and improvements are mapped out for future research.

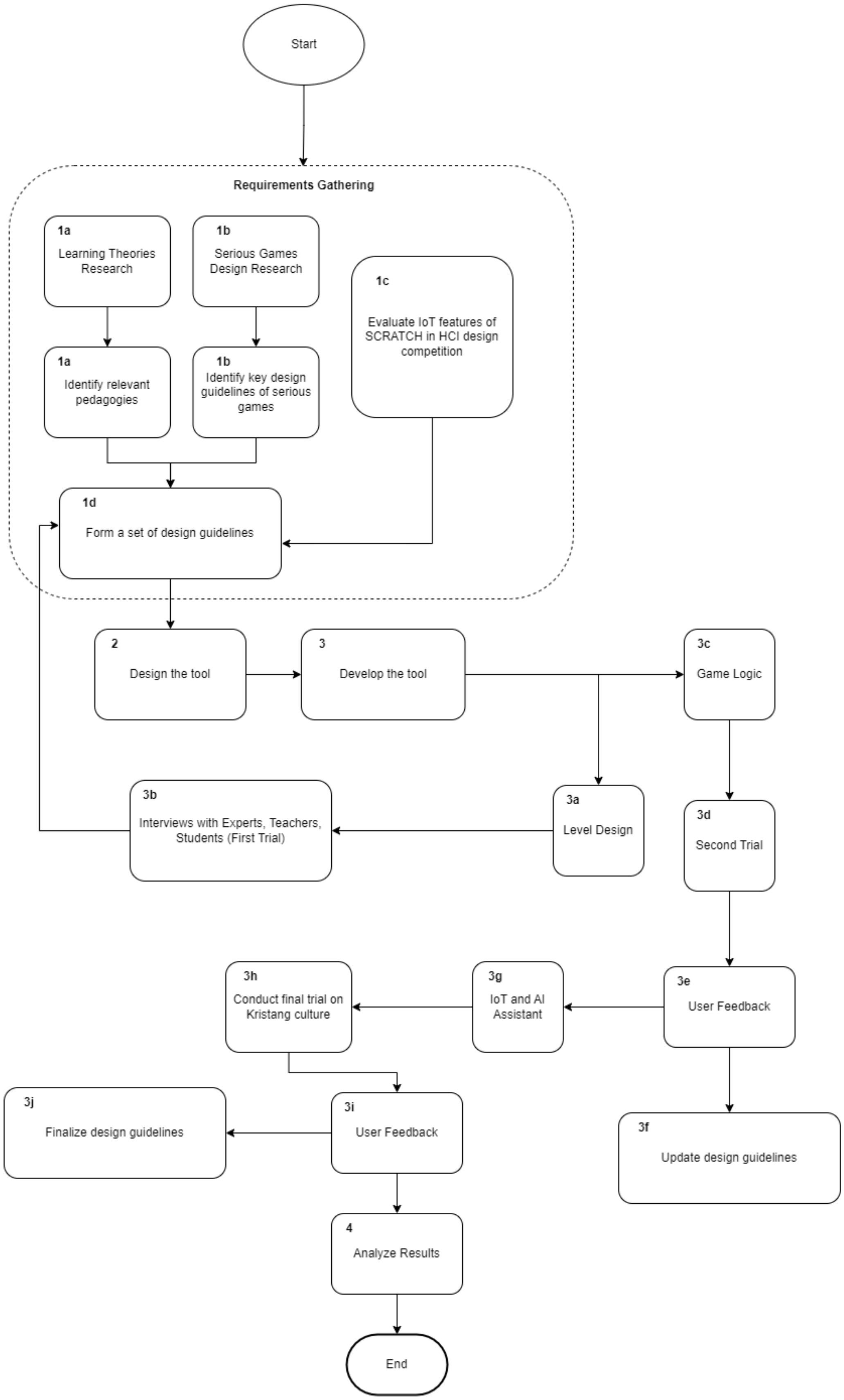
Start
Requirements Gathering
1a
Learning Theories Research
1b
Serious Games Design Research
1c
Evaluate IoT features of SCRATCH in HCI design competition
1a
Identify relevant pedagogies
1b
Identify key design guidelines of serious games
1d
Form a set of design guidelines
2
Design the tool
3
Develop the tool
3c
Game Logic
3b
Interviews with Experts, Teachers, Students (First Trial)
3a
Level Design
3d
Second Trial
3h
Conduct final trial on Kristang culture
3g
IoT and AI Assistant
3e
User Feedback
3j
Finalize design guidelines
3i
User Feedback
3f
Update design guidelines
4
Analyze Results
End

Figure 3.2 Research Workflow diagram

3.4 Population and Sampling

This section discusses how the participants in this study were chosen and recruited, and what criteria they had to meet, what sampling procedures were used, and the ethical considerations for each. It will list the requirements for each user trial separately.

3.4.1 Short User study: Evaluating Scratch with Raspberry Pi

Population: The target population for this study consisted of students at the University of Nottingham Malaysia. They were from various disciplines and faculties, ensuring a diverse range of academic backgrounds and perspectives.

Sampling: A convenience sampling method was utilized for this study. Participants were recruited through an email invitation sent to the entire student body. Those interested in participating were instructed to sign up via a provided link.

A total of 39 students responded to the email and signed up to participate in the study. This sample size was determined by the number of students who volunteered within the recruitment period.

Sampling Procedure: The recruitment email contained information about the study, including its purpose, procedures, and the voluntary nature of participation. Students who signed up were asked to provide informed consent before participating in the trials.

Given the convenience sampling method, the representativeness of the sample relative to the larger university student population may be limited. However, efforts were made to include students from different academic years and fields of study to enhance diversity within the sample.

Ethical Considerations: The study received ethical approval from the University of Nottingham Malaysia Institutional Review Board. All participants were informed about the study's objectives, their right to withdraw at any time, and the confidentiality of their responses. Informed consent was obtained from each participant before the commencement of the trials.

3.4.2 Short User study: Feedback on inclusion of IoT int the tool

Population: The study targeted students aged 11 to 15 from two middle schools. This age range was selected to capture a diverse array of educational backgrounds and developmental stages within the middle school demographic.

Sampling: A convenience sampling method was utilized. Participants were recruited through connections with local schools and word of mouth within the community.

A total of 56 students participated in the study. The sample size was based on the number of students who volunteered and whose parents provided consent within the recruitment period.

Sampling Procedure: The recruitment process involved informal communication and networking within the community and through connections with local schools. Information about the study was shared with students and their parents, who were then invited to participate.

Parental consent was obtained for all participants under the age of 18. To enhance the diversity of the sample, efforts were made to include students from multiple schools. However, the convenience sampling method may affect the representativeness of the sample relative to the larger population of students aged 11 to 15.

Ethical Considerations: Ethical approval was obtained from the University of Nottingham Malaysia Institutional Review Board. Comprehensive information regarding the study's aims, procedures, and voluntary participation was provided to both the participants and their parents. Written consent was obtained from the parents or legal guardians of all participants. Participants were assured of their right to withdraw at any time and the confidentiality of their responses was maintained.

3.4.3 Trial 1: Design Features Evaluation and Future Suggestions

Population: The target population for the interviews consisted of individuals with relevant expertise and experience in the field of education. This included:

- 2 cultural experts
- 3 teachers (2 education lecturers and 1 school principal)
- 3 university students (2 first-year education students and 1 PhD education student)

This diverse group was chosen to provide comprehensive insights into the research topic.

Sampling: A purposive sampling method was employed to select participants for the interviews. Participants were recruited through professional connections facilitated by the main and co-supervisors of the study.

A total of 8 individuals participated in the interviews:

- 2 cultural experts recruited through the main supervisor's professional network.
- 2 education lecturers and 1 school principal recruited through the main supervisor's professional network.
- 2 first-year education students and 1 PhD education student recruited through the co-supervisor's network.

Sampling Procedure: Participants were identified and approached based on their relevance to the study. The main supervisor leveraged professional connections to recruit the cultural experts, education lecturers, and the school principal. The co-supervisor utilized their network to recruit the university students.

All participants were contacted via email, where the purpose of the study and the nature of their participation were explained. Participants agreed to take part in the interviews and consented to have their interviews recorded for the purpose of results analysis. No formal consent forms were signed, but agreement was obtained through email communication.

Ethical Considerations: The study received ethical approval from the University of Nottingham Malaysia Institutional Review Board. Although no formal consent forms were signed, participants provided their consent via email. They were informed about the study's objectives, the voluntary nature of their participation, and the confidentiality of their responses. Participants were assured that their identity would remain confidential in the analysis and reporting of the results.

3.4.4 Trial 2: Evaluating initial usage of the tool

Population: The study targeted school students aged 11 to 13. This age range was selected since the tool is targeting students around that age range.

Sampling: A convenience sampling method was utilized. Participants were recruited through connections with a local school, and their parents were contacted via word of mouth.

A total of 22 students participated in the study. The sample size was based on the number of students whose parents agreed to their participation within the recruitment period.

Sampling Procedure: The recruitment process involved informal communication through connections with a local school. Information about the study was shared with the students' parents, who were then invited to consent to their children’s participation.

Parental consent was obtained for all participants under the age of 18. Although the convenience sampling method may affect the generalizability of the findings, efforts were made to include a diverse sample from the local school.

Ethical Considerations: Ethical approval was obtained from the University of Nottingham Malaysia Institutional Review Board. Parents were provided with comprehensive information regarding the study’s aims, procedures, and voluntary participation. Written consent was obtained from the parents or legal guardians of all participants. Participants were assured of their right to withdraw at any time and the confidentiality of their responses was maintained.

3.4.5 Trial 3: Evaluating the tool using Kristang culture as a case study

Population: The target population for this study consisted of middle school students aged 12 to 13. This age range was selected since the tool is targeting students around that age range.

Sampling: A convenience sampling method was employed for this study. Participants were recruited through a local connection with a large middle school, which provided access to a substantial number of students. Recruitment efforts involved word of mouth and multiple visits to the school.

A total of 96 students participated in the study. The sample size was achieved through persistent recruitment efforts and obtaining parental consent for participation.

Sampling Procedure: The recruitment process involved direct engagement with a large middle school through existing local connections. Information about the study was shared with students during visits to the school, and parents were subsequently contacted to obtain consent for their children's participation.

All interactions with potential participants and their parents were conducted to ensure that parents were fully informed about the study's purpose and procedures. Parental consent was obtained for all participants.

While the convenience sampling method may limit the representativeness of the sample relative to the broader population of students aged 12 to 13, efforts were made to ensure a diverse sample by engaging with a large middle school.

Ethical Considerations: The study received ethical approval from the University of Nottingham Malaysia Institutional Review Board. Detailed information about the study's objectives, procedures, and voluntary participation was provided to the students and their parents. Written consent was obtained from the parents or legal guardians of all participants. Participants were informed of their right to withdraw from the study at any time and were assured of the confidentiality of their responses.

3.5 Requirements gathering

This section discusses all the steps that were taken to acquire the requirements that defined the design and development of the game authoring tool. This includes initial research into learning theories and serious games, conducting a small trial to evaluate a game authoring tool with Raspberry Pi, analysing the results from a trial conducted by the same researcher on a serious cultural game developed prior to this research and also gathering feedback on the use of IoT in the form of RFID cards in that same game. Finally, further requirements were gathered after interviewing experts, teachers, and education students after viewing the initial prototype of this game authoring tool.

3.5.1 Researching learning pedagogies and serious games design approaches

The first step in gathering requirements for the design and development of this tool was to research the learning pedagogies most relevant to the objectives of this study. The maker pedagogy and the multiliteracies pedagogy were the most relevant studies as they included the three main integral teaching methods that the tool would be used to deliver the learning material. Constructivism and constructionism are learning theories that inspired the maker pedagogy and therefore are not mentioned separately since they are assumed as a big part of the maker pedagogy.

The three main teaching methods derived from the learning theories mentioned above are:

1) Learner-centered learning where the learner is the main focus, and the educational tool would focus on giving control to the learner to lead their own learning journey.
2) Experiential learning which is a cornerstone when it comes to teaching with games as the learner is actively learning by doing.
3) Personalized learning which is crucial in the tool as it will offer the freedom to design games and create stories in various forms and using different design assets.

These main key points were crucial when designing the features of the tool and careful consideration was taken to make sure the tool included these approaches. Researching on serious games and how they are designed was very effective to find the best way to design a tool that creates well-designed serious games while also incorporating the three teaching methods mentioned above.

3.5.2 Analysis of existing 2D game authoring tool Scratch & Raspberry Pi

The objective of this trial was to test an existing prototyping tool that allows Raspberry Pi to be used without knowing how to code and see how participants could use it to create an interactive prototype. The trial was also conducted using Scratch which is a very well-known software for creating games without code and is therefore considered as a competition to this tool, although the two tools have significant differences between them. Based on the results of this trial, important lessons could be learned, and strengths and weaknesses of Scratch could be determined to help in improving the toolkit developed in this research.

Prior to the competition the participants had a field trip to Malacca, a UNESCO World Heritage Site and home to the Peranakan culture. They got to visit different museums and got to know about the different cultures in Malaysia. On the day of the competition, they had the main goal of developing a quick prototype using Scratch 3 on the Raspberry Pi 4 that would be based around one of the cultural artifacts that they saw on their trip. They were provided with sensors ranging from touch sensors, infrared sensors, LEDs and RFID card readers.. They were split into different groups and the participants were all undergraduate students and from different courses.

3.5.1.1 Conduction of survey

After the competition was over each of the 39 participants were given a paper survey to fill. The survey included ten questions in total asking very simple questions about their experience in using Scratch 3 with the Raspberry Pi and their feedback about it. The questions in the survey are posted in APPENDIX B: Questionnaire 1.

3.5.1.2 Participant demographics

The experiment had a total of 39 participants between the ages of 18 and 28. The mean age value was **20.72** ($\mu = 20.72$) and a standard deviation value of **1.716** ($\sigma = 1.716$), reflecting the ages of the undergraduate students who were mostly in their first and second years of study, which is further reflected in Table 3.1.

Table 3.1 Analysis of Q1 (See APPENDIX B: Questionnaire 1)

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Q1	39	18	28	20.72	1.716
Valid N (listwise)	39				

The experiment also consisted of **18** males and **21** females with **46.2%** and **53.8%** respectively as depicted in Table 3.2, which means that the experiment was almost half males and half females so as to avoid biased conclusions involving a majority gender.

Table 3.2 Analysis of Q2 (See APPENDIX B: Questionnaire 1)

Q2

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	21	53.8	53.8	53.8
	Male	18	46.2	46.2	100.0
	Total	39	100.0	100.0	

The next questions involved understanding whether the participants have any prior experience in using any version of Scratch and using any model of the Raspberry Pi. This is important to know because participants who might have used these technologies before might find it easier to use these technologies and might therefore be biased towards answering that using Scratch with the Raspberry Pi was easy.

Table 3.3 shows that the majority of the participants have indeed used a version of Scratch prior to this experiment with **76.9%** or **30** participants having used it before compared to only **23.1%** or **9** participants who have not.

Table 3.3 Analysis of Q3 (See APPENDIX B: Questionnaire 1)

Q3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	9	23.1	23.1	23.1
	Yes	30	76.9	76.9	100.0
	Total	39	100.0	100.0	

However, Table 3.4 shows how the opposite result was noticed regarding the participants having prior experience in using a Raspberry Pi. In this case only **9** participants or **23.1%** have used a Raspberry Pi before while the majority of **30** participants or **76.9%** have not used a Pi before. This shows that Scratch is much more popular among the participants and the Raspberry Pi is a relatively new topic for them.

Table 3.4 Analysis of Q4 (See APPENDIX B: Questionnaire 1)

Q4

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No	30	76.9	76.9	76.9
	Yes	9	23.1	23.1	100.0
	Total	39	100.0	100.0	

3.5.1.3 Participant feedback on using Scratch 3 with Raspberry Pi

Participants were asked about their experience of using the Raspberry Pi with Scratch 3, how easy the setting up process was, how challenging was the task of connecting sensors to the Pi, how hard was it to come up with a prototype idea using Scratch and the Pi from Question 5 to 9. Finally, how user-friendly was the GUI of Scratch and how useful was it to include the Raspberry Pi with Scratch.

According to Table 3.5 when the participants were asked to rate how hard or easy the task of setting up the Raspberry Pi with Scratch was, the majority seemed to agree that it was more hard than easy. While some participants opted for the extremely easy and the extremely hard answer, the mean value was **5.97** ($\mu = 5.97$, $\sigma = 2.096$, $\sigma^2 = 4.394$) which indicates slightly hard. Based on the standard deviation and the variance values it could be concluded that answers did differ slightly from the mean indicating that some participants found it even more difficult while others thought it was easier. However, overall, it could be said that the participants found it slightly hard to set up the Raspberry Pi with Scratch.

Similarly, the participants found it slightly hard to connect the sensors to the Raspberry Pi with a mean value of **5.79** (μ = 5.79, σ = 1.936, σ^2 = 3.746). This is understandable given that most of the users have not used a Raspberry Pi before and connecting the sensors of the Pi for the first time could be a rather complex task. Coming up with the prototype was also a slightly hard task for the participants given the time constraint and the use of a new tool, the mean value of **6.03** (μ = 6.03, σ = 1.814, σ^2 = 3.289) indicates that conclusion. With those values of standard deviation and variance it also indicates that some participants found it very hard to come up with a prototype idea, while some did find it relatively easy, but the majority found it more towards hard than easy.

When the participants were evaluating the user-friendliness of the GUI of Scratch the results were more towards neutral which indicates that the majority agrees the user-friendliness was average. The mean value of their answers is **5.46** (μ = 5.46, σ = 2.138, σ^2 = 4.571) and the high value of variance indicates that an equal number of participants find it either extremely user-friendly or extremely not user-friendly. That shows that the participants were not impressed by the interface given the fact most of them have used some sort of Scratch before and therefore a better result was expected.

Finally, when asked about the benefit of including the sensors into the prototype which is some sort of IoT into the process the majority indicated that it was somewhat beneficial with a mean value of **6.74** (μ = 6.74, σ = 2.348, σ^2 = 5.511) but the high variance value shows that some minor participants thought it was of no benefit almost. However, those participants remain as the minority while some participants thought it was extremely beneficial leading to a conclusion that overall, the participants found that the sensors did add some sort of benefit.

Table 3.5 Analysis of Q5 – Q9 (See APPENDIX B: Questionnaire 1)

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Q5	39	9	1	10	5.97	2.096	4.394
Q6	39	8	2	10	5.79	1.936	3.746
Q7	39	8	2	10	6.03	1.814	3.289
Q8	39	8	2	10	5.46	2.138	4.571
Q9	39	9	1	10	6.74	2.348	5.511
Valid N (listwise)	39						

The last question asked the participants to write down a short paragraph about any additional feedback or suggestions they had for the trial, or the software and technology used. These answers were categorized under several suggestions which are:

- Easier guide (explaining how to use the Pi with Scratch)
- Insufficient time (to come up with an idea and implement it)
- More sensors
- No feedback (these participants left the question empty)
- No negatives (these participants wrote positive feedback only)
- No technical experience (meaning the participant did not have technical expertise, especially those not from computer science courses)
- Raspberry Pi connection issues (Pi keeps disconnecting, issues in connecting, etc.)
- Sensor issues
- Software issues (related to Scratch issues)

Table 3.6 shows the frequencies of each of these suggestions where it could be noticed that a quarter of the participants complained about the time not being sufficient **(25.6%, N = 10)** , connection issues with the Raspberry Pi was the second issue (**15.4%, N = 6),** the lack of sensors was called out by **12.8%** (**N = 5)** and a similar number of participants had no feedback and left the question empty. One tenth of the participants felt an easier guide explaining how to start the process was required (**10.3%, N = 4)** while **3** participants each (**7.7%)** had software and sensors issues leading to total of **6** participants facing issues in making their prototype due to faulty sensors and Scratch software bugs. Only **2** participants

(5.1%) had no negative feedback and said everything was fine while **1** participant (**2.6%)** complained that the task was hard given the lack of technical experience.

Table 3.6 Frequencies table for the feedback given by the participants

Feedback

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	No technical experience	1	2.6	2.6	2.6
	No negatives	2	5.1	5.1	7.7
	Sensor issues	3	7.7	7.7	15.4
	Software issues	3	7.7	7.7	23.1
	Easier guide	4	10.3	10.3	33.3
	More sensors	5	12.8	12.8	46.2
	No feedback	5	12.8	12.8	59.0
	Raspberry Pi connection issues	6	15.4	15.4	74.4
	Insufficient time	10	25.6	25.6	100.0
	Total	39	100.0	100.0	

Based on the results from the trial, some key points were noticed that would need to be improved, which are:

1) The participants complained about the lack of time, and it was also observed that many groups could not use Scratch for a sufficient period of time to test it out due to the lack of time. This was important and therefore the final trial in this research included enough time to make the trial go smoothly.
2) The participants complained about connectivity issues with the Pi which could be resolved by investing in getting better USB-C cables.
3) Some participants complained about the lack of sensors. This is a tricky problem to navigate since the type of sensors used matters, and more sensors does not always mean a better experience.
4) Very few participants complained that Scratch was not user-friendly, which stresses out on the fact a user-friendly interface is very important in any application, and especially an educational one.

It can be noticed overall that some of the complaints were not related to Scratch but rather the design of the trial. Therefore, it is important to note that the trial format has to be designed carefully to assist the participants and help them focus on the task at hand.

Overall, the usage of Raspberry Pi in the trial was not without concerns so it is important that it is included in a smart manner and to provide as much support as possible to facilitate users in using it.

Reference: (Abdulrazic, et al., 2022)

3.5.3 Analysis of an existing cultural IoT game of Malacca

Previous work done by the researcher included a serious cultural game about Malacca that incorporated IoT, and the results from a trial on that game are useful in designing the serious game making tool. Previous work done by (Abdulrazic, 2019) shows the impact of using an IoT-enabled serious game on cultural heritage. The research develops a 3D virtual game in first-person format where the player explores Malacca as a trader and gets to learn about its culture through interacting with other characters in the game using RFID cards. Furthermore, the player can trade spices inside the game using RFID cards as money. Abdulrazic (2019) highlights how the participants gained knowledge about the Malacca culture by playing the game, which proves that first-person exploratory 3D virtual games with storytelling aspects could be a good method of designing serious cultural games.

3.5.4 Feedback on inclusion of IoT into the tool

In an effort to include a unique aspect into the tool and an interesting method to interact with the games designed, an IoT feature seemed appropriate. That inclusion might provide a more immersive scenario and captivate the learner’s attention more. IoT could be included in many different forms with some forms more appropriate than others. Regardless of which way it is to be included, it needs to add meaning and be useful.

A short study conducted on 56 students aged 11 to 15 was conducted to get feedback on the inclusion of IoT in the example cultural serious game discussed in Section 3.3.3 so that the participants can get a feel of how IoT would look like inside a game. After that the participants tried to design small game scenes using the first prototype of the tool without IoT included yet and then they were asked short questions about their feedback on IoT being included. Fig. 3.3 shows the research flow diagram of the study conducted.

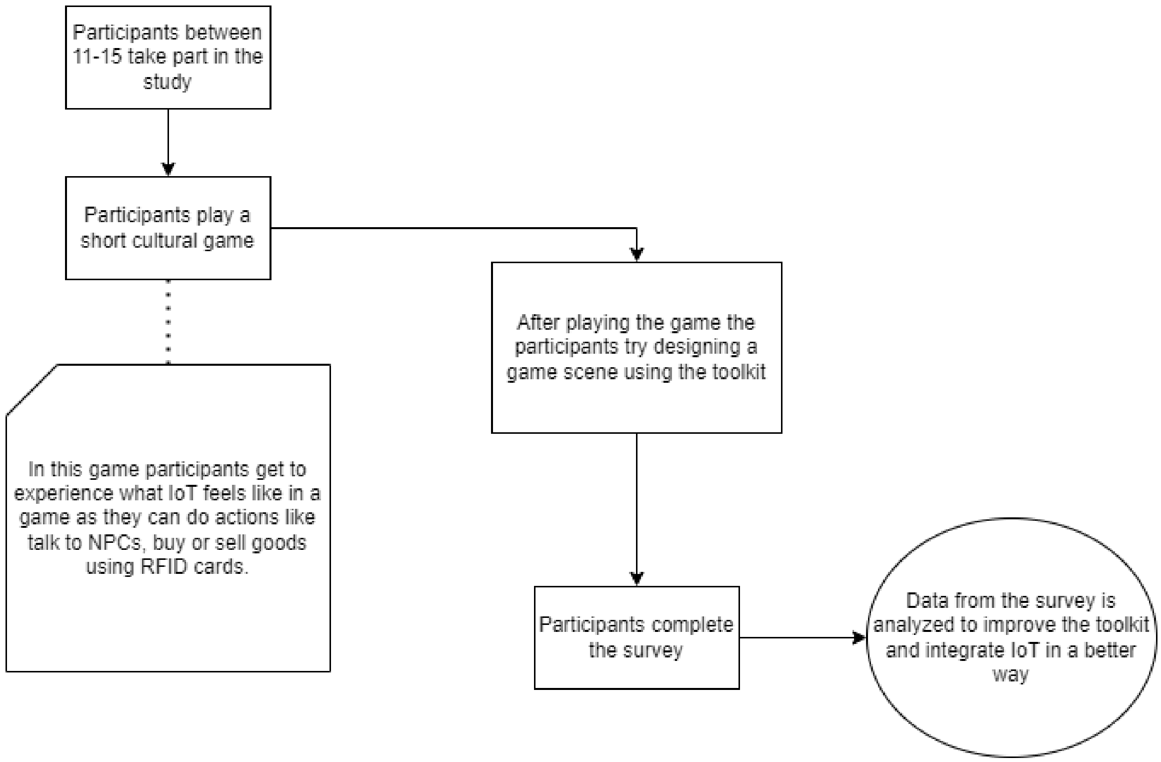

Figure 3.3 The flow of the study conducted to determine IoT inclusion in the tool

The participants included 38 males and 18 females with an average age of **12.93** years. After trying both the IoT cultural game and designing a small game scene in the tool they were asked 6 short questions on a linear scale of 1 to 5 with 1 being highly disagree and 5 being highly agree. The 6 questions asked are listed in APPENDIX B: Questionnaire 2.

In total, 47 participants mentioned that they found the cultural game authoring tool to be an effective way to share cultural heritage in an immersive way. However, only **6 (10.17%)** participants chose 5 regarding integrating IoT in the game to be engaging, while **39 (69.64%)** participants chose 4. Moreover, **53 (94.64%)** participants mentioned that they enjoyed making a short scene with the game authoring tool prototype, and **48 (85.71%)** participants liked the use of RFID cards in the game, where **9 (16.07%)**

participants chose 5 and **39 (69.64%)** chose 4. Furthermore, **55** (**98.21%)** participants showed interest in using RFID cards as actions in the game. Lastly, **53 (94.64%)** participants did not find the authoring tool prototype hard to use while designing the game scene, where **38 (67.86%)** participants chose the scale of 5 and **15 (26.79%)** participants chose the scale of 4. A simple bar chart depicting the answers to the survey can be seen in Fig. 3.4.

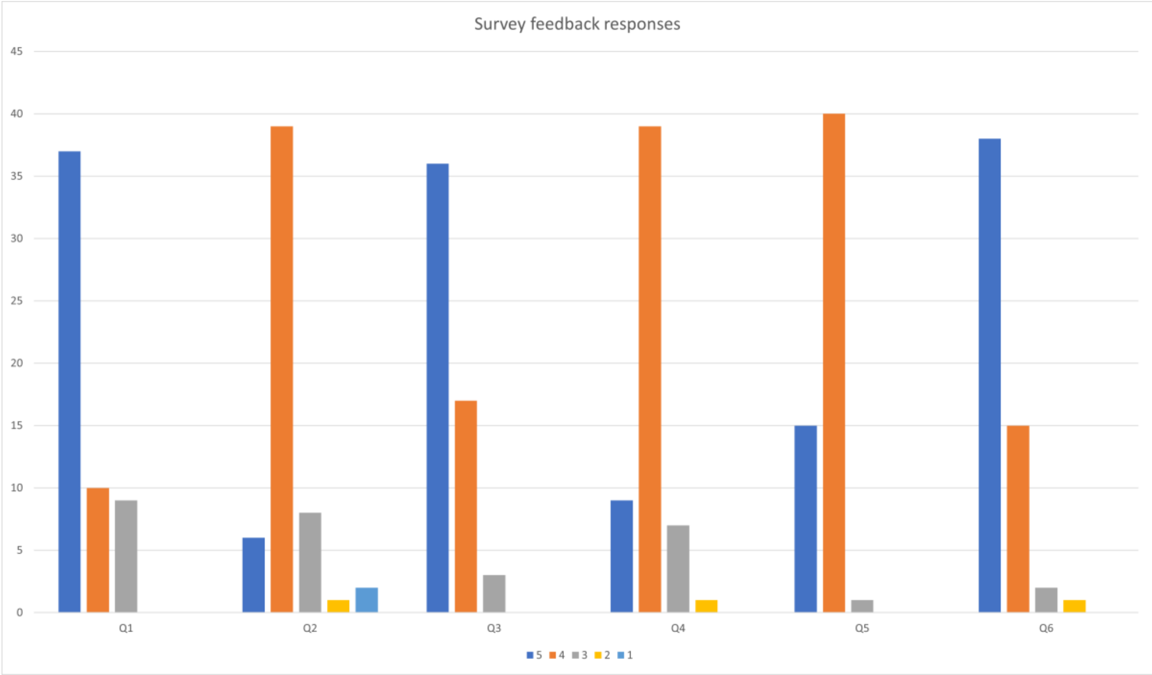

Figure 3.4 The responses to the questionnaire of the IoT inclusion study

The study showed that the participants were interested in IoT inclusion into cultural games and that might make them more receptive to including IoT into their own designed games. On the contrary to the study discussed in Section 3.4.1 where the participants did not enjoy using the Raspberry Pi with Scratch, in this study the participants were more eager. Multiple conclusions can be made here, first of which is the age. Younger participants might be more willing to try new things and more interested in IoT unlike older participants who might find it to be more of an obstacle. Second, in this study the Raspberry Pi was already set up with the sensors attached and therefore the participants did not need to deal with that part unlike the other study where the participants had to fix their own Raspberry Pi and connect their own sensors. Finally, it can be deduced that the format in which IoT is included is very important as it could be a welcome addition or an inconvenience.

Reference: (Abdulrazic, et al., 2022)

3.5.5 Feedback on proposed tool from interviews

Additionally, formulative evaluation was used through interviews and focus study groups involving the early prototype to help determine the direction of development with museum and cultural organisation professionals, teachers and education students involving 8 participants. The expert participants are denoted by an E followed by the participant number, teachers are denoted by a T and students are denoted by an S. The details of the participants can be viewed in APPENDIX A: Interviewee Details . Details of the interviews are discussed in Chapter 4, and Chapter 5. Moreover, literature review analysis of serious games design frameworks and learning theories have been reviewed and crucial points have been integrated into the initial design guidelines in Section 3.6 and in the finalized design guidelines in Chapter 5.

Each of the interviewees was made to watch a short video demonstrating the first feature of the tool which is the level design feature. They were then asked different questions asking them about their opinion on the tool as they have seen it, what could be improved, how can it be used, etc. The feedback was positive overall with a few main key points:

- The tool has the potential to be able to communicate better with the younger generation as it speaks more to them.
- The tool cannot replace the traditional teaching methods but would be best as a supporting tool to enforce the learning material.
- A detailed learning plan will be required in order to integrate the tool into classrooms.
- It is very crucial for the tool to have accurate 3D models of a specific culture to allow the users to create real immersive realistic games.
- The tool has a user-friendly interface and is easy to navigate and understand.

- The tool should help in guiding the users and assist them in designing their games.
- It would be useful if the tool allows the users to upload their own materials, in the form of audio, images, models, etc.

3.6 Design Guidelines

This research adopted a participatory design approach and therefore the design guidelines were constantly getting updated as more feedback, and more trials were conducted. This section discusses the design guidelines that were used to develop this tool, including all the changes acquired from interviews and trials. The design guidelines discussed in Chapter 5 is a culmination of best practices based on literature review, learning theories and feedback from this research, but not every point from those guidelines were utilized in the development of this tool due to financial and development constraints. The design guidelines listed below however were all utilized for this tool.

1. **The tool needs to have easy to use, flexible buildings tools to design levels –** Level design is very important for serious cultural games as how the scene looks like could already influence the players and teach them about the culture. According to the design framework developed by (Andreoli, et al., 2017), the design phase of designing a serious game scene is an iterative one. The user keeps visiting this phase after gaining more information about the culture and refining the story, so it is very important that the tools in the tool that allow for scene manipulation to be easy to use and flexible. Good implementation of this point would assist in integrating both the learner-centered and personalized learning approach discussed in Sections 2.3.1 and 2.3.3.
2. **The tool should highlight the important cultural assets that the user can use –** This could be done by either providing critical information about those assets for the user designing the level, to imply the significance or by making sure that particular asset stands out when deployed in the scene using different methods like visual effects or special lighting to highlight the asset. This is inspired by the study conducted by (Raptis, et al., 2019) which evaluated how visual search tasks were affected by the way those visual aspects were implemented. By highlighting those

visual aspects or assets the knowledge acquisition of the users could increase. This was also based on the results of the interview with experts E1 and E2 (See Section 4.2 and confirmed further by the teachers T2 and T3 (See Section 4.2.3). This promotes both the learner-centered approach and the personalized learning concept.

3. **The tool needs to provide robust logic tools to allow the users to add the cultural information easily –** When it comes to any cultural game, the learning component is one of the most important components in designing that game. Being able to add the information easily through the game logic should be in a very easy way so that the user can focus more on what content to add rather than suffer from trying to add it in the first place. The research done by (Ibrahim, et al., 2015) shows the cultural information in a virtual cultural heritage environment is one of the most important factors to facilitate cultural learning. A very important point that is crucial to assist the users in learning in their own way which works seamlessly with the learner-centered approach and allows for variety of options to design games which is a form of personalized learning.
4. **The assets, especially the cultural assets used in the tool need to be of high quality rendering –** According to the experiments done by (Ibrahim, et al., 2015) the users were more interested in the virtual environments that had better quality assets, which means that the assets used need to be of high quality in order to keep the players attracted and attentive. Also confirmed by the feedback from T3 (See Section Teachers). High quality assets will provide an immersive environment which will enhance the experiential learning approach that the developed games will provide for the learners.
5. **The tool should contain several audio elements, like background noises, music to enhance immersion–** This is a very important guideline as discussed by (Schofield, et al., 2019) on how the people interviewed in their research recognized sounds as one of the key elements that makes them think about their culture and how it adds to that sensory knowledge and provides a more immersive experience. Similar to the point above, a better immersive experience would lead to a more effective experiential learning approach.**Teachers**

6. **The tool should be personalized, allowing the users to edit existing assets by changing their names, colours, or shapes** – This was a suggested idea by multiple interviewees, precisely T1 and S3 (See Section 4.2.3). This aligns well with the personalized learning approach and encourages the learners to experiment and learn in their own way which also aligns with the learner-centered approach.

Chapter 5 includes a more comprehensive set of design guidelines with a few more guidelines that could not be included in this tool due to financial and development constraints. However, they are beneficial for future research and to serve as a deliverable based on the extensive research conducted in this study.

3.7 Hardware

The hardware used in this research is straightforward and not too complex. The tool is a desktop-based application that can only run on the Windows operating system. However, to run the tool MacOS or Linux would require a few tweaks but is not impossible. For the purposes of the study the Windows operating system was sufficient.

An average computer was used to develop the tool running on a moderate i7 8750H CPU, 16 GB of RAM and a GTX 1060 6GB GPU. Computers with lower configurations should still be able to use the tool without an issue considering the tool does not demand much. A thorough test was not done to identify the exact minimum hard requirements needed since all testing took place on the computer the tool was developed on, however, a computer with a 6th generation CPU, 8 GB of RAM, and a dedicated GPU with at least 2 GB of RAM should be able to run it. Other minor requirements would require an empty ethernet port to connect to the Pi and an empty Universal Serial Bus (USB) port to power the Pi. If the Raspberry Pi has its own power adapter, then the USB port is not needed.

As for the requirements of the Raspberry Pi, this tool would work on any Pi version starting from 2. The only additional requirement would be having an external Wi-Fi dongle for Raspberry Pi 2 which does not have a dedicated Wi-Fi chip. That is in case connecting to the Wi-Fi is necessary in order to connect to the computer connected on the same Wi-Fi network. The tool itself does not require an internet connection to run. The latest Raspberry

Pi 4 was used for this study as its computing power makes it an optimal choice, provide faster sensor reading speeds and ensuring the trials go smoother.

3.8 Software

The tool is developed with the Unity game engine. All the codes in the tool are written using the C# programming language. The assets in the tool are retrieved from multiple sources, some paid and some are free. Due to the scale of the development, the work was divided into three main stages:

1) **Level designing features**: This feature includes adding different game objects on the scene, scaling them, rotating them, deleting them, changing their location and when applicable changing their colour or texture. Unlike most game authoring tools, this tool allows the user to be a part of the game while it is being designed, navigating the environment with their very own first-person character having a crosshair to decide where to place new objects.
2) **Game logic features**: This feature allows the users to add quests to their games and complete their games. The users can create all their quests from a simple interface and choose form three different quest templates and link the story flow to create their games.
3) **Enhancing features and QoL (Quality-of-Life) additions**: These are the features that would enhance the accessibility of the tool and provide a better user experience. These include adding RFID input support by allowing the users to connect a Raspberry Pi with an RFID sensor and mapping the card input to specific action in their games. This also includes adding ChatGPT as a virtual assistant to help the users come up with their game's stories. Finally, it includes adding a story archive with historical stories about Kristang; the culture target for this study, so that the users can always refer back to

them and get inspired for their stories.

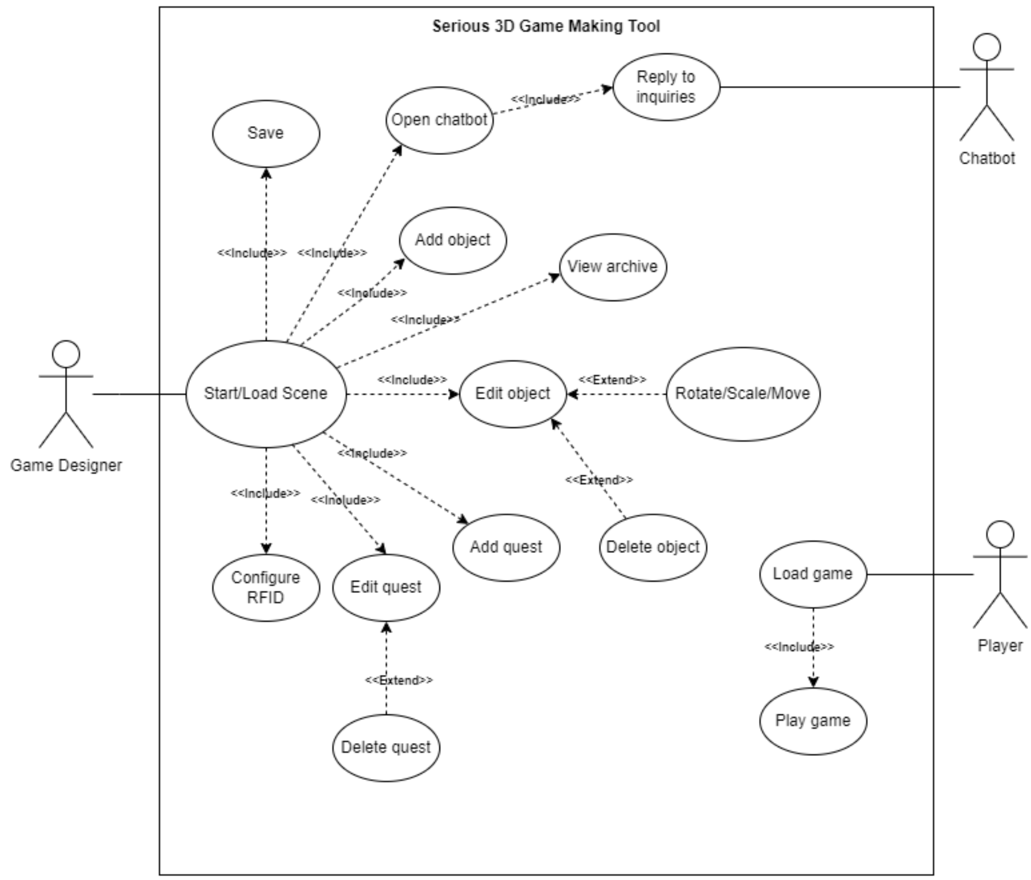

Figure 3.5 Use Case diagram

Figure 3.5 demonstrates a simple Use Case Diagram that briefly shows the functions of the system. There are three main actors; two of those are of the users that differ based on their usage type. The Game Designer actor is the role the user takes when they are designing a game. They can start a new scene or load an existing one, they can add objects to the scene, modify existing objects or delete them, add quests, modify quests, or delete them. They can also configure RFID card input, chat with ChatGPT and save the scene. The other role a user can take is that of a Player, where the user loads a scene and plays the game. The final actor is the Chatbot which is ChatGPT interacting with the Game Designer to answer their inquiries.

3.9 Storyboard

This section provides a very brief story board about how the tool developed by this research could be used. One of the examples is demonstrated in the story board, a classroom environment. First, it starts with the class teacher giving a lesson about the Kristang culture, this obviously could be any other culture, but Kristang is being used for this example. Second, the teacher would then ask each student in the class to create a small serious game about the culture they just learned about. Each student uses his or her imagination to create a simple game that has important learning elements about the culture they learned about while also adding their own personal touch into the game.

Furthermore, the students would then go around their classroom playing each other's games, creating a social environment where the students are engaging together to learn while also enforcing the information learnt in the class through the various games played. Each student could use their creativity to bring about a game that is truly unique and helpful. This method showcases how the three teaching methods discussed and researched in Section 2.3 are being utilised. Each student is actively learning by designing a game which is a learner-centered approach. The variety of assets means every user is having a personalized learning experience and finally the users playing the designed games are active participants in an experiential learning experience. The storyboard illustrations are below. Created by Storyboardthat.

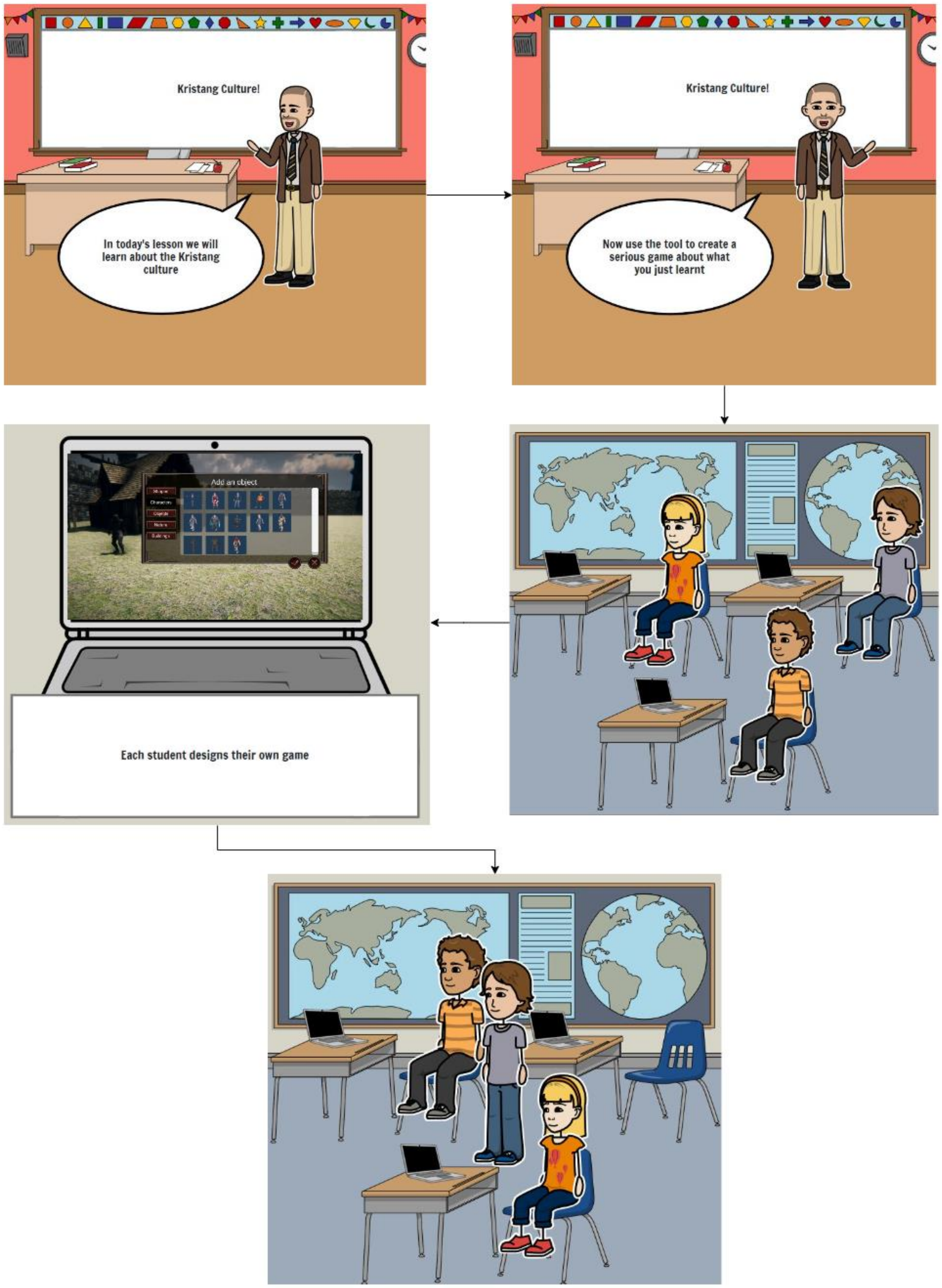

Figure 3.6 A storyboard illustration of a use case for the tool in a classroom

3.10 Development of Proposed Game Authoring Tool

This section discusses some of the software functional and non-functional requirements, followed by a brief description of how each development milestone was achieved. Furthermore, the section includes a class diagram, with all the classes created for the tool excluding third party classes from external libraries imported into the tool.

3.10.1 Software Requirements Specification

3.10.1.1 Functional Requirements (FR)

There are several functional requirements in this tool, however, only the main ones will be highlighted here.

Table 3.7 Main Functional Requirements

FR01	The tool should allow the game designers to save or load a scene.
FR02	The game designer should be able to add various objects to the scene, including characters, buildings, shapes, trees, etc.
FR03	The game designer should be able to edit any object they have added, rotate it, scale it, move it and for some objects, change the color or texture.
FR04	The game designer should be able to add game logic to the designed game through a user-friendly interface. The interface should allow the game designer to create quests and manage the flow of the story.
FR05	The game designer should be able to connect a Raspberry Pi to the tool, configure RFID cards, and map specific pre-defined tasks to be controlled using the RFID card instead of keyboard input.
FR06	The game designer should be able to communicate with the virtual assistant ChatGPT to inquire about stories related to the Kristang

	culture. ChatGPT should only responds to questions about the Kristang culture and reject other questions politely.
FR07	The players should be able to play any game saved on the tool. This includes only the saves on a particular local machine. Cloud saves are not supported.
FR08	The tool should allow the players to play the game and follow the sequence of quests set by the game designer.
FR09	The tool should contain an archive feature containing simple stories about the Kristang culture for users to refer to.

3.10.1.2 Non-functional requirements (NFR)

Like any software development, there are also a few non-functional requirements.

Table 3.8 Main Non-Functional Requirements

NFR01	The tool should be able to run on any computer device with average specifications. It should have at minimum a 6th generation i3 CPU or the AMD equivalent, 8 GB of RAM, and a dedicated GPU with at least 2 GB of RAM.
NFR02	The tool should be able to program sensor logic from any Raspberry Pi 2 or newer. The Pi must be connected, a simple command line program should be running, and the sensors connected must be from the list of supported sensors. If using Pi 2 a wireless dongle will be needed.
NFR03	The tool should be able to run without an internet connection. The Raspberry Pi does not need an internet connection either, however, both the computer and the Pi should be on the same connection to be able to connect. The easiest way to accomplish this is to have both of them running on the same network which might require them to connect to a router.

NFR04	The tool can only be used using a mouse and a keyboard, no other external input peripherals are supported. Input from supported sensors can only be used for specific actions using the Raspberry Pi.

3.10.2 Level Design

The tool includes an average number of assets, however, due to financial constraints it was not possible to include a big library of Kristang cultural assets.

The development started by creating a basic empty scene, with proper lighting conditions, post-processing effects, etc. Setting the main character for the user to use which is a first-person character was then implemented. After making sure the user can move the character around it was time to set up the features that will help the user design a feature.

This was divided into several parts:

1) Creating the interface where the user can choose game objects to add.
2) Adding the game object the user selected onto the scene, where the crosshair is pointing at (similar to shooting games). The game object had to be levelled directly on the terrain surface, not below it or above it.
3) Creating a GUI and a (Heads Up Display) HUD for the editing interface, to edit game objects. A HUD is basically a user interface component that will be on the user's screen while they are using the tool to provide important information related to their current task. These are usually user interface elements they cannot click on but only provide visual guidance.
4) Implementing each of the editing features, the rotation, the scaling, changing the position and also changing the textures of some of the objects.

The level design features allow the user to navigate the game scene in first-person view, choosing the area they want to place an object in, open the build menu and selecting the asset that they want to add, and left clicking their mouse to add the object where the crosshair is pointing.

They can also approach an already placed object and edit its location, rotation, scale, and for some objects their color and texture. These features were mostly achieved by creating a Spawn Manager class that handled adding new objects to the scene. There were helper classes responsible for storing each object’s information, so that they could be retrieved, modified, saved, and loaded. A centralised UI Manager class handles all the user-interface interactions and updates.

Below are some screenshots of the level designing features showcasing the different interfaces used to design the game scene.

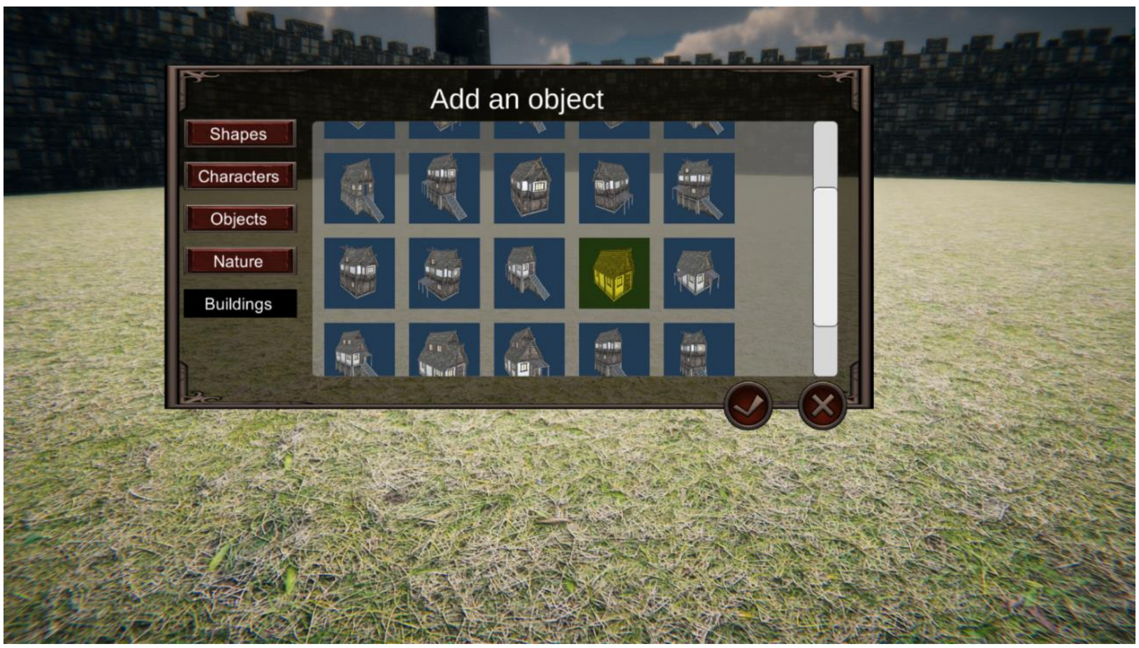

Figure 3.7 Menu where the user can choose game objects to add (In this example, buildings)

Figure 3.8 User is placing an object (this house was just placed)

Figure 3.9 Menu to edit a game object (in this case it's the nearest tree)

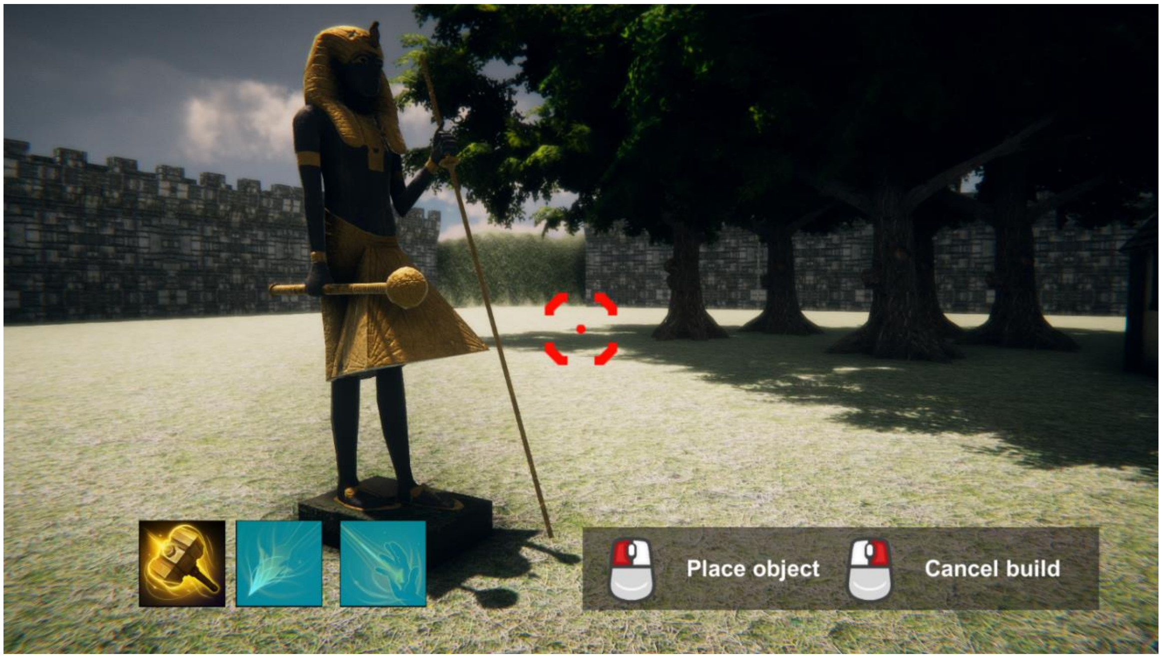

Figure 3.10 A cultural artifact being placed, more artifacts like this will need to be added

3.10.3 Logic Features

The logic features of the tool are one of the most important aspects of the software. They allow the users to add life to their games and design a complete game. The most common way to allow non-programmers to write logic code without actually coding involves the usage of visual programming blocks. Visual programming blocks are used in SCRATCH and similar tools. They allow the users to drag and drop certain logic blocks including but not limited to conditional blocks, triggers, etc.

They come in various complexities, for example, the visual programming blocks for SCRATCH are intended to be used for young children and are therefore very simple to use. On the other hand, some visual programming blocks are complex and intended for professional use as seen in the popular Unreal Engine's blueprint system.

However, this research adopted a more simplistic approach to allow users to add logic in the game. The main reason behind not using visual programming blocks is the complexity involved in initially implementing it. Since the tool is focused on cultural games only, there was no need for a wide range of logical operations that might require the visual programming blocks. Instead, a simpler approach of using forms with drop down lists, radio buttons, and text fields was used.

The users would typically design their game scenes and add NPCs around the scene that they want the players to interact with in order to progress in the story. While designing the scene, the users can open a specific window to add quests to their game. They use a simple menu that guides them through the steps needed to add a quest. Common features allow the users to name their quests, choose when they get activated (start of the game or after a specific quest ends), specify the reward for finishing the quest, which NPCs are involved, etc.

Moreover, they can edit any quest they have added before or even delete them. To safeguard the logic of the game and avoid game breaking bugs, for example, in the event where the user deletes a quest that was required in another quest, there were measures implemented to warn the user about not being able to delete a quest that is needed elsewhere. Similarly, the user will not be able to remove any NPC from the scene that is involved in a quest, to prevent a game breaking bug from occurring when the players are playing the game.

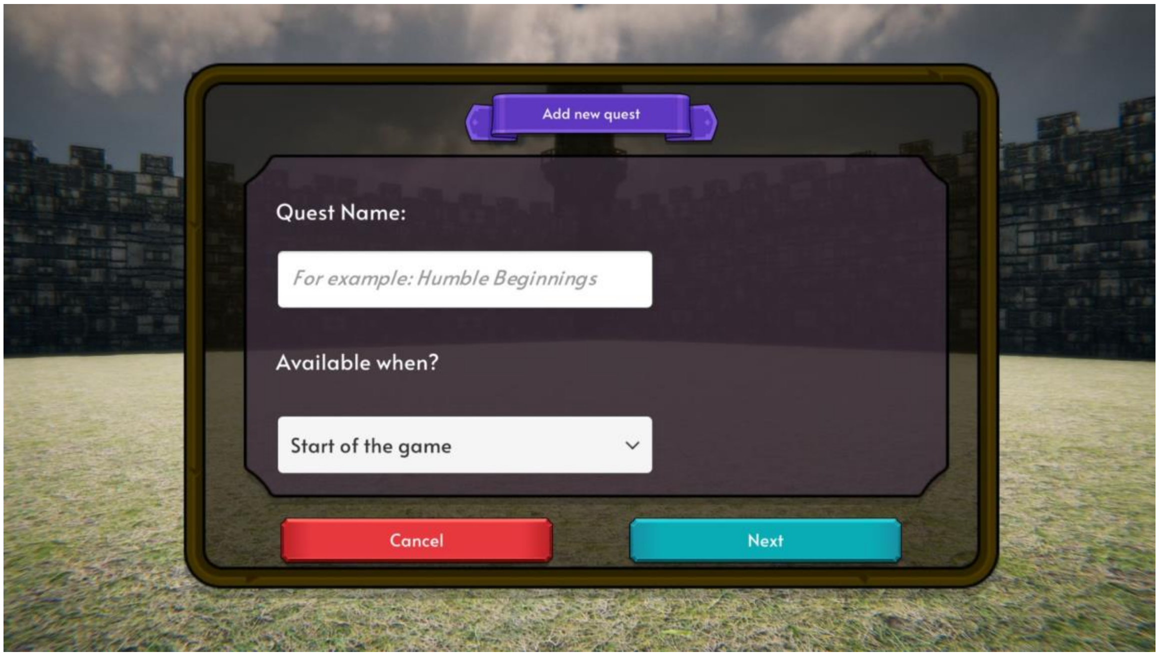

Figure 3.11 A screenshot of the quest creating GUI

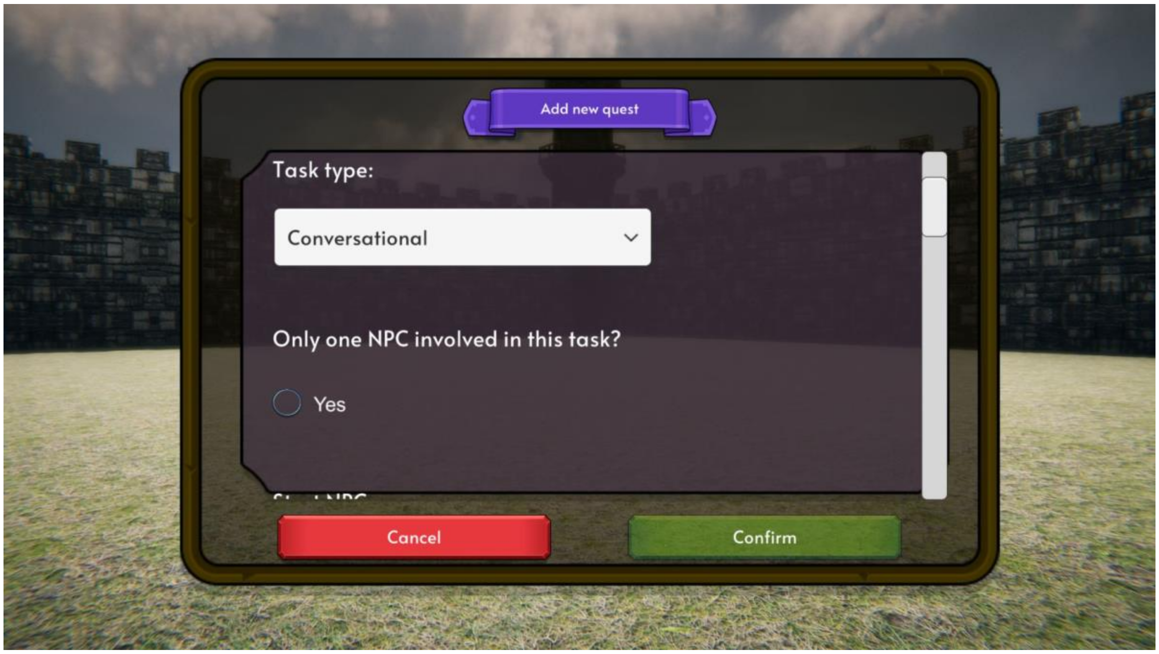

Figure 3.12 Another screenshot of the quest creating GUI

These features were mostly implemented by creating a Quest Manager class that contains top-level functions that control the quests. A separate Quest class was created that acts as a container with helper functions for each quest created. To keep everything organized and separated two separate classes were created for deleting and editing the quests. A GUI

Metadata class was also created to store the information obtained from the user while creating the quest and transfer it to the created Quest objects.

3.10.4 Saving & Loading Features

Undoubtedly in any software, being able to save and load our work is one of the most crucial aspects. This tool is no different and therefore a robust saving and loading system was implemented. At any given moment while the user is designing their game, they can open the menu and save their work. By default, the tool saves their work in the default save location used by Unity.

In short, when the user saves their work a reference of all the variables that make up their current game scene and logic are stored in various data forms ranging from text to numbers and also Booleans. A custom interface was designed within the tool to allow the user to view all the existing save files. A prompt appears when the user tries to save a file with an existing name, asking the user if they would like to overwrite the saved file.

Figure 3.13 The loading window where users can load their work

Similarly, to load a file, the user can open the menu and choose the option to load. They can select from the list of existing save files on the computer. It is also possible to transfer the saved files from one machine to another and simply place it in the same folder where the other files are. It is to be noted that by default every save file will load into the designing mode, but the user can easily press a single button to enter the play mode where they get to play the game. Game progress cannot be saved but it should not be a problem considering that most of the developed games are relatively small and can be finished within a few minutes.

3.10.5 IoT Integration

The IoT integration in this tool is implemented through a Unity plugin prototype developed by (Huang, et al., 2021) and demonstrated on a card game. The Unity plugin in question works using two major steps:

1. Python code installed on a Raspberry Pi runs and reads sensor data, which is then sent over the local network to the plugged computer using WebSockets.
2. A Unity plugin connects to the Pi and retrieves the sensor data read by the Pi.

Currently the Unity plugin supports three sensor types, namely the touch sensor, IR sensor and RFID sensor. There is a basic setup that needs to be complete in order to get this plugin to work. The Raspberry Pi being used has be the 2^{nd} model or newer.

The sensors get connected to the Pi in the normal way it always does, there is no extra step needed here. To connect multiple sensors a GPIO extender needs to be used to increase the number of pins available to connect those sensors. Finally, the Pi needs to be connected using an ethernet cable to the computer being used. For the first time running the Pi the VNC viewer is needed to view the screen of the Pi in order to run the Python code that reads the sensor data.

Implementing the logic inside Unity requires the plugin to be imported and installed. The plugin consists of a prefab that allows the user to connect Unity to the WebSocket port where Pi can send sensor data over. The logic behind the plugin is relatively simple, it connects to the local area network shared with the computer at a certain port and listens for data being passed over. All retrieved sensor data are processed as JSON files which can then be read in Unity and prepared for use.

The major disadvantage in using this plugin is the steps needed to be able to get it to run, however, the participants in this research would not need to worry about setting it up as it will be ready for them beforehand. Fig 3.14 shows a basic overview of how the process of reading sensor data and sending it to the tool works.

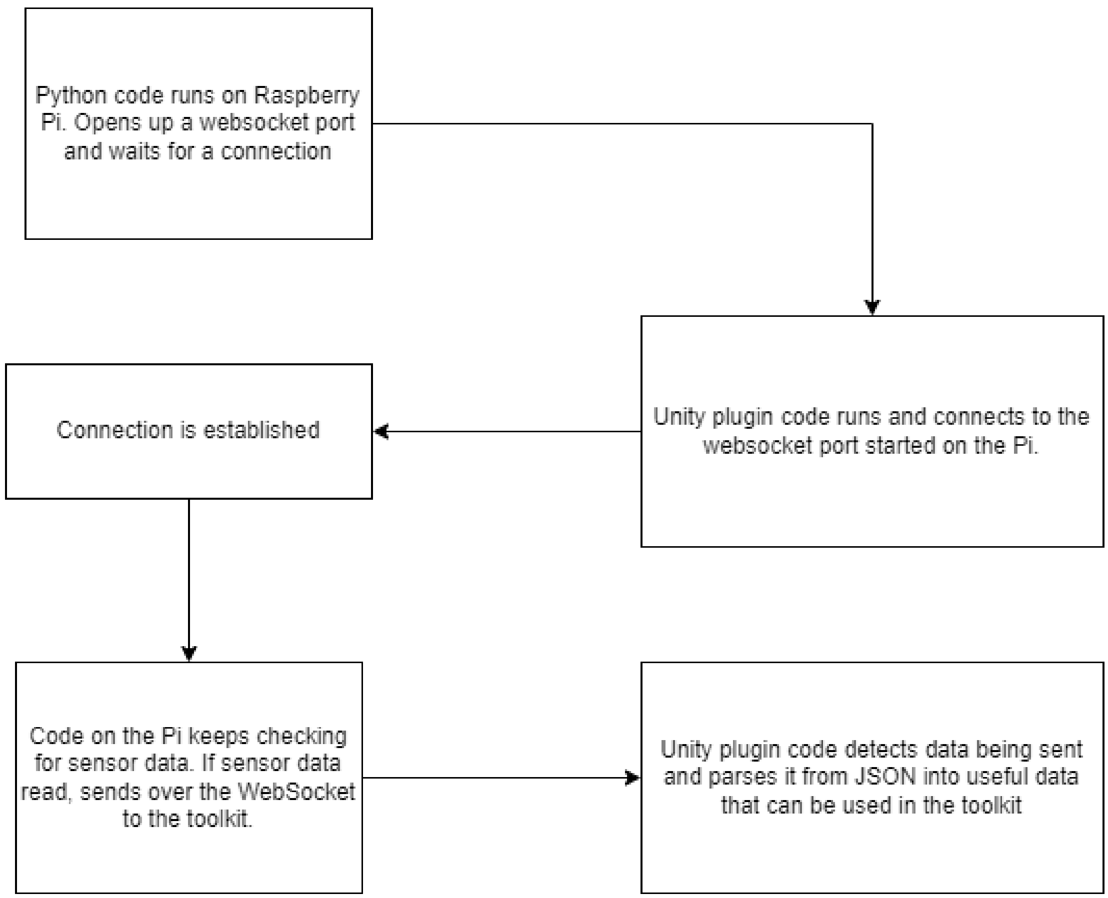

Figure 3.14 IoT sensor reading process overview.

The way the users would actually use this feature is by configuring the sensor they want while designing the game. They can choose from a set of fixed actions that would be triggered by the input of the sensor. For example, the user can choose a specific RFID sensor to trigger conversations with NPCs instead of a keyboard button. Fig 3.19 shows the window that the user utilizes to configure the sensors.

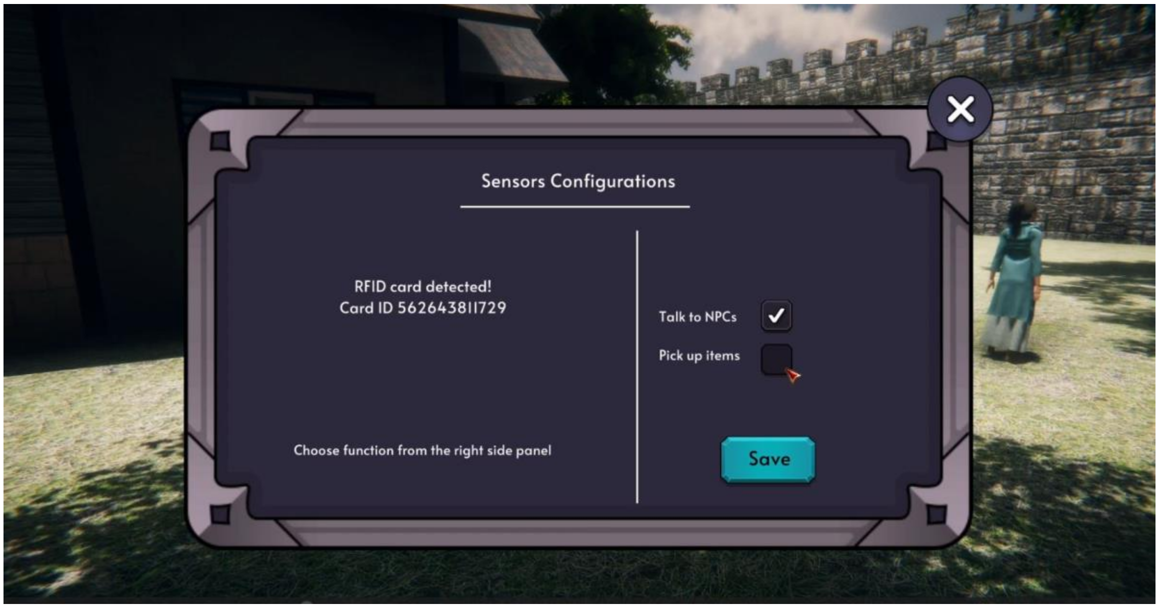

Figure 3.15 Sensor configuration window

3.10.6 Artificial Intelligence Integration

The Artificial Intelligence integration in the tool was in the form of an AI assistant that can help the users come up with story ideas for their games. It can help them double check facts or suggest some as well. The best form to integrate this feature is through a chatbot like feature where the users can chat with the AI assistant.

For this research, the most common and widely popular natural language model ChatGPT (OpenAI, 2023) was used. Since it is already a very extensively trained model and gives accurate answers most of the time, it was a suitable solution. To integrate ChatGPT into the tool, an API key from OpenAI, the developer of ChatGPT, was required. There is no specific code required to communicate with ChatGPT, and instead traditional HTTP request methods were used.

The ChatGPT documentation was concise and clear on how to send prompts and what to expect as the output. All the output was in JSON format which is easily parsed inside Unity. A simple chatbot interface was designed where the user can write prompts to ChatGPT and get a reply. ChatGPT was configured to limit its responses to questions about the Kristang culture only and limit the response character limit to 500 characters. Fig 3.20 shows how the chatbot window looks like.

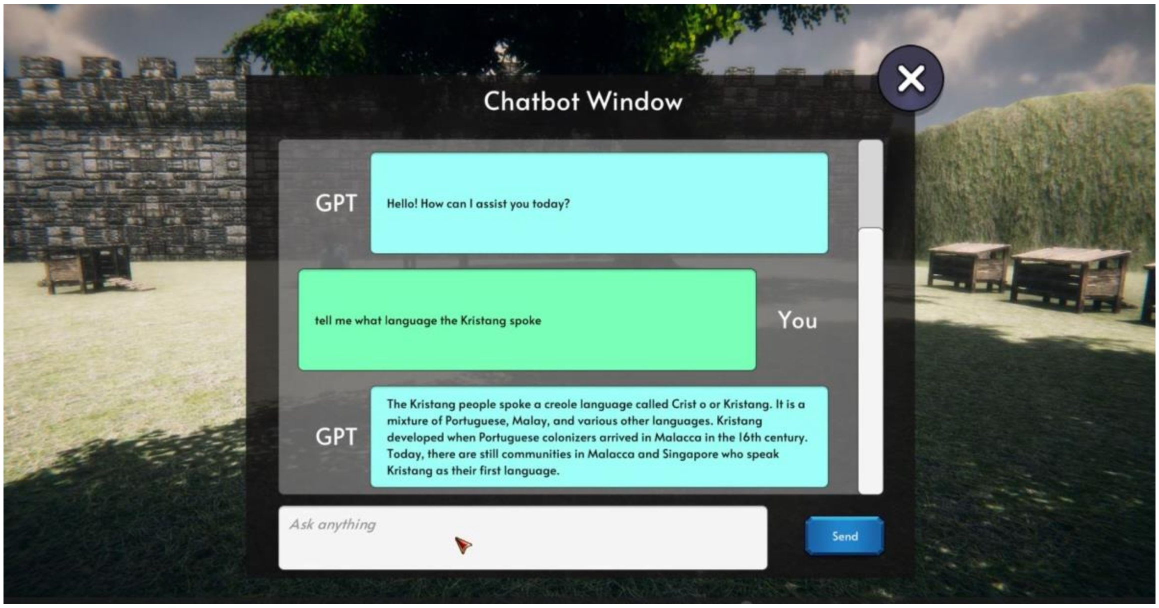

Figure 3.16 ChatGPT assistant window

3.10.7 Class Diagram

Due to the nature of the tool, there are many class files involved and displaying them in one place is not easy or ideal. However, a class diagram can give a clearer picture about how the tool is designed and what the classes are doing. Due to space constraints, two class diagrams are depicted in the report. The classes related to the quests are in one class diagram and the rest of the classes are in the other. The class diagrams can be seen below:

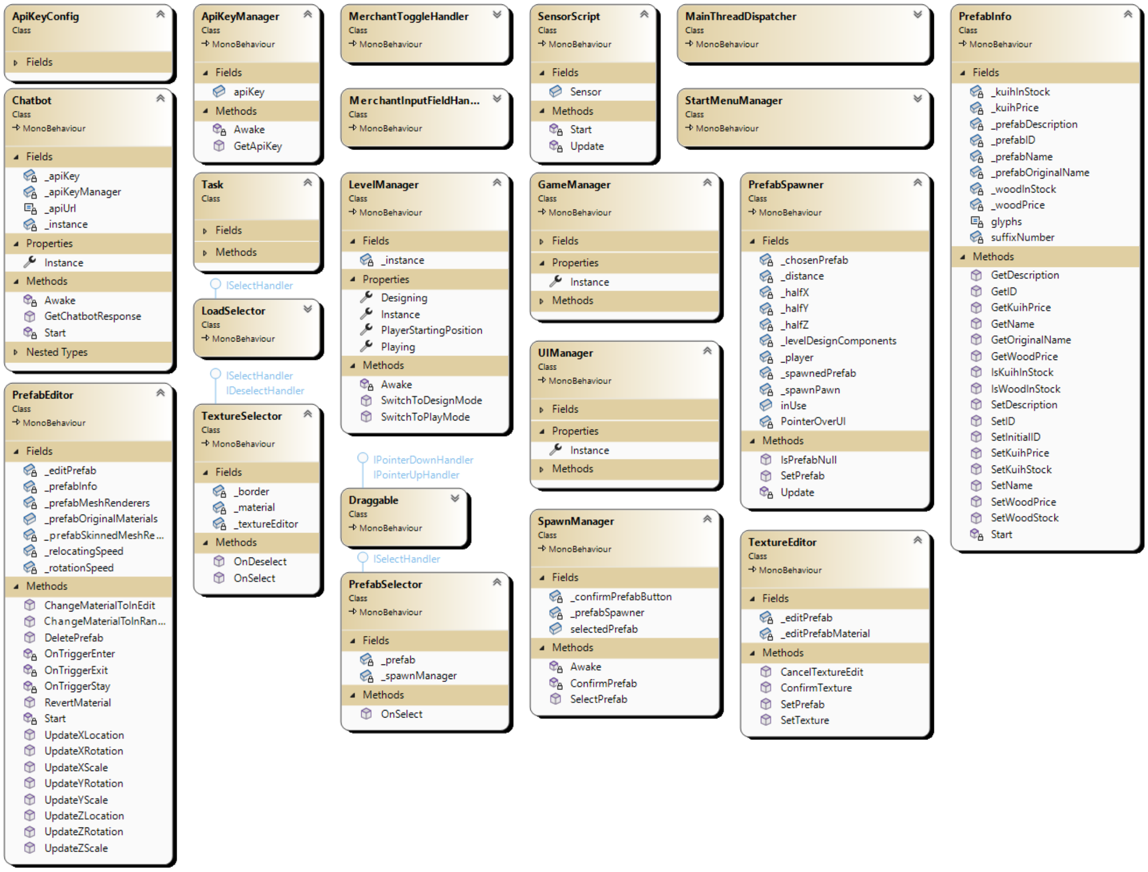

Figure 3.17 Class Diagram (First Part)

This class diagram has the majority of the manager classes that manage the flow of the tool. Most of the fields and methods were hidden in the diagram due the size of the diagram. Every unique component in the tool has a corresponding class to manage it, and for the bigger components they are multiple smaller-sized classes that add up to that component. An example would the classes managing the prefabs when it comes to designing the game scene. The class PrefabEditor for example is responsible for editing existing prefabs, while PrefabSelector simply saves the prefab that the user is selecting for the GUI. Major classes like GameManager and SpawnManager each act as managers for a major task. GameManager manages the entire flow between all the classes, while SpawnManager for example manages the process of spawning prefabs into the scene.

From the diagram smaller classes can be seen, like classes to manage Toggles, store API configuration for ChatGPT, or even managing the start menu. The following class diagram focuses on the classes used in the quest system:

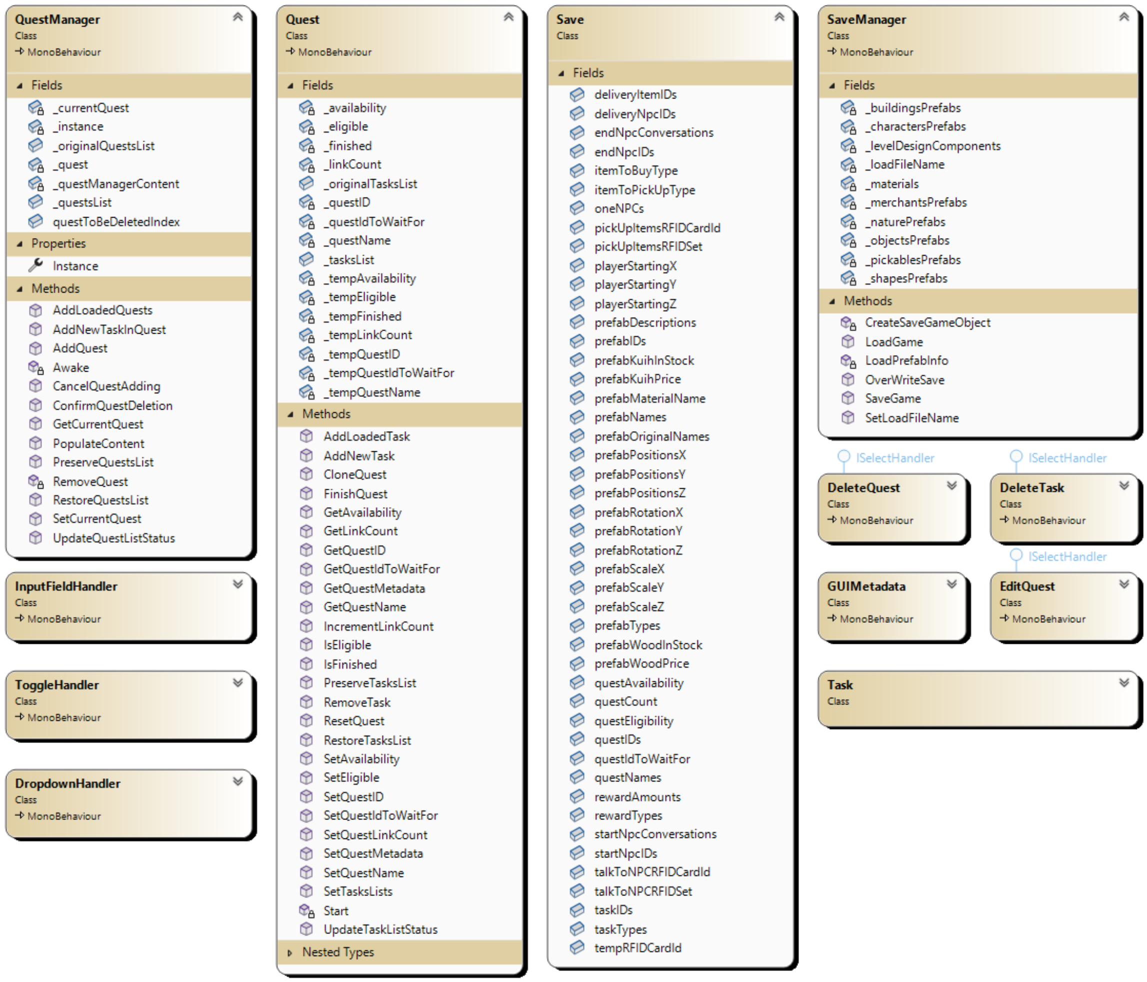

Figure 3.18 Class Diagram (Second Part)

The quest classes are some of the lengthiest in the tool as they store a large number of fields with corresponding get and set methods. They are smaller classes to delete and edit quests which are smaller in size. The Quest Manager is the central class managing the flow and calling all the other classes together.

Throughout both the class diagrams there are no lines indicating relationships between the classes and that is mainly due to how Unity operates. Unlike traditional object-oriented programming languages, Unity has a different flow where all classes inherit from the base class MonoBehaviour. The MonoBehaviour class is needed on every class in Unity that will get attached to any game object on the scene. If any class is modifying a game object, or even modifying the interface then they have to inherit from MonoBehaviour. The only few classes that are not inherited from MonoBehaviour are the ones simply used for storing data like the Save class file which is a serializable class file simply acting as a temporary storage for save data. Some classes use different interfaces like the ISelectHandler which allows the code to read data from different interactions on the GUI, mostly the selecting action. Similarly, there are other interfaces used like IDeselectHandler, IPointerUpHandler and IPointerDownHandler.

3.11 Measurement Instruments Design and Development

This research employed two main instruments to collect data and feedback from the participants, through interviews and questionnaires. The interviews were only utilized in the first trial during the pandemic, and they took place virtually. Questionnaires, however, have been utilized for all the other tests, the minor trials while collecting requirements and the main trials testing the tool.

3.11.1 Short user trials

The short studies mentioned in Sections 3.4.1, and 3.4.2 consisted of short questionnaires focusing on a very specific objective in the initial stages of the study. The design of the questionnaires in those studies included a short demographics section and the rest of the questions were in a Likert Scale format probing the participants about their experience. For the trial in Section 3.4.1 questions 3 and 4 were to understand the user's experience with the two tools being tested in that trial, namely the Scratch application and the Raspberry Pi. Questions 5 to 9 were concerned with the user's experience with using Scratch and Raspberry Pi, asking them about different aspects like interface, difficulty of use, and how they felt about the benefit of incorporating sensors into game creation. Q10 was an open-ended question to gather general feedback and improvement suggestions. Construct-wise, there were three main constructs, first being past user experience which is Q3 and Q4, second being user experience which is Q5 to Q9 and finally would be suggestions which is Q10. All the questions in this questionnaire were validated with the main supervisor of the research. The questionnaire can be viewed in APPENDIX B: Questionnaire 1.

For the short study in Section 3.4.2 it consisted of fewer questions and mostly had one construct which is user experience, however, under that construct are two sub-constructs, one targeted specifically for IoT user experience and one for the tool itself. Q1, Q3, and Q6 were targeted more towards the user experience of the tool itself, while Q2, Q4 and Q5 were focused on the user experience when using IoT. Similarly, this questionnaire was validated with the main supervisor of the research. The questionnaire can be viewed in APPENDIX B: Questionnaire 2.

3.11.2 Interviews

The interviews did not include a fixed set of questions, and instead adopted an open-question approach in a casual discussion session. However, there were key points that were asked to ensure the objectives set for the interviews were met. The main objective of the interviews was to gather feedback from experts, teachers, and education students about the initial prototype of the tool and get suggestions on how the tool could move forward and provide benefit in the intended way set in the research objectives to make sure the tool developed addresses the problems in the Problem Statement (Section 1.2).

The main supervisor of the research was present in all interviews to make sure they went smoothly and stayed on topic. The interviewees were all shown the tool and demo and asked about their honest opinion and first impressions. They were then asked about how they think this tool can be used to educate about culture, in which settings it can be used and the best ways to do so. Furthermore, they were asked about their suggestions and what features they liked and which ones they would like to see in the future.

The main reason there was no fixed set of questions is because not all interviewees belonged to the same group and each group had some questions specific to them. For example, the cultural experts were asked about how to best represent culture, use the tool in real-life scenarios like museums and cultural exhibitions while the teachers were asked more questions about how the tool can be an effective educational tool, on how to integrate it into school curriculums and how to supervise the learning process. The education students however, being younger and more tech savvy, were asked about how the tool aligns with learning theories, how the tool resonates with younger generations, and how to improve the tool further to captivate the younger generations into learning about culture.

To ensure that no valuable information from the interviews was lost, they were all recorded and all the relevant feedback from the videos were transcribed for analysis. Specific quotes from the interviews can be viewed in Section 4.2 where the feedback is analyzed thoroughly and in a more comprehensive manner.

3.11.3 Main user trials

The main questionnaire-based user trials of this research are the second and third trials. The second trial evaluated the usage of the tool after the features of level designing and adding game logic were concluded. It consisted of school students who tried designing a short game and also played a demo game. However, this trial focused on the user experience and not the learning impact. The third and final trial had two separate groups with one group reporting on their user experience and one group being tested for the learning impact of using the tool.

The second trial's questionnaires consisted only of Likert Scale questions, besides basic demographics like age and gender, and had one main construct which is user experience. However, the questions were designed to evaluate the different aspects of user design, ranging from interface to controls to quest variety and general user experience. Likert Scale was the best instrument to evaluate these questions as it allows the users to rate their experience based on a range of numbers and makes analyzing the data more efficient and accurate, compared to open-ended answers which might be interpreted in a wrong way, or not provide enough context. The main supervisor double-checked and validated the survey questionnaire before it was used in the trial. The questionnaire can be viewed in APPENDIX B: Questionnaire 3.

Finally, the third user trial consisted of multiple questionnaires, each responsible for measuring specific constructs. The questionnaire used for the first group focused on the user experience, however, in a more extensive way than the questionnaire in the second trial. Besides basic demographics questions, the questionnaire asked the user about their experience with video games and which tool they were using in the trial, the game maker tool or the control group's tool, the storyboard. All the questions were in the Likert Scale format besides the question about which tool they used which was a multiple choice. The questionnaire was a mix of original questions asking about the experience when using the tool, the participants used and a set of questions derived from the research done by (O'Brien, et al., 2018) which measure the immersion of a user when using a specific tool. Therefore, this questionnaire had the basic constructs about past experience (Q1), tool choice (Q2), tool user experience (Q3 to Q6), trial experience (Q7 and Q8) which were asked to evaluate if the trial had enough time and if the users asked for help due to technical issues, and finally the user immersion construct (Q9 to Q20). The questionnaire was validated with the main supervisor of the research. The questionnaire can be viewed in APPENDIX B: Questionnaire 4a.

The second group was evaluated using three questionnaires, however all three had the same questions. The questions were all related to knowledge constructs, to test out the knowledge of the participants about the topic being taught. Each question was testing a particular knowledge construct based on an educational fact being taught through the serious game on the tool or the slides. One questionnaire was given before the trial, one right after the trial and one five days after the trial. All the questions were in multiple-choice format since the users had to choose the correct answer out of four choices. The questionnaire can be viewed in APPENDIX B: Questionnaire 4b.

3.12 Main User Trials

3.12.1 Trial 1: Design Features Evaluation and Future Suggestions

As mentioned earlier, this research consisted of three main trials to evaluate the tool and its features. An initial trial evaluated the designing features of the tool and asked experts, teachers, and students about their general opinion of the project and what could be included to achieve the goals set by this work.

3.12.2 Trial 2: Evaluating initial usage of the tool

This was followed by the second trial that allowed some school students to use the tool after it could create games with their own logic. This trial focused on the user experience when it comes to both designing games and playing them. This was important to get insights into what can be improved and to fine-tune the tool further before the last main trial.

3.12.3 Trial 3: Evaluating the tool using Kristang culture as a case study

The last trial was the biggest trial and consisted of the largest number of participants thus far. All of the participants were school students and were split into two main groups. The first group tested the designing feature of the tool. This was done by splitting that group into two and letting half of them create a story about the Kristang culture using the tool, and the other half created a story using a storyboarding website.

Both groups were provided with the same reading material to read and come up with a story from and allocated the same time limit, which was 15 minutes. After the trial each student filled in a survey that asked questions related to user experience and immersion, to evaluate how interested the students were in the tool compared to the storyboarding website. Storyboarding is considered a maker tool and was therefore more ideal to test against than compared to, for example allowing that group to make stories using pens and paper.

The second main group was tested for learning gain, memory retention and knowledge retention when it comes to learning about the Kristang culture. To test this, the group was split into two as well, with one group playing a pre-made game designed using the tool by the researcher to teach certain key elements about the Kristang culture while the other group had only presentation slides that contained the same information, but in a more traditional passive way. They each had 20 minutes to play the game or read the slides.

All participants were required to fill out a survey testing their knowledge about the Kristang culture using various questions at three different times: (1) an initial survey before they either read the slides or play the game, (2) a second time right after they are done with the slides or playing the game, (3) finally, a third time after five days have passed. This is important to measure learning gain, knowledge retention and memory retention.

Put simply, learning gain measures how many students managed to answer a question correctly after they have answered it incorrectly before the trial. Since learning gain is a metric that measures the impact directly, the other two metrics help in gaining a better understanding. Memory retention calculates how many participants remembered their answer to any given question after the five days have passed, be it right or wrong. This is an important metric to test their memory. Finally, knowledge retention measures how many participants remembered the correct answer after the five days, which means they managed to retain that knowledge and not forget what they learned. This method of measuring the impact on learning is demonstrated in (Sanzana, et al., 2021). Figure 3.19 shows a flowchart depicting the methodology of how the final trial was conducted.

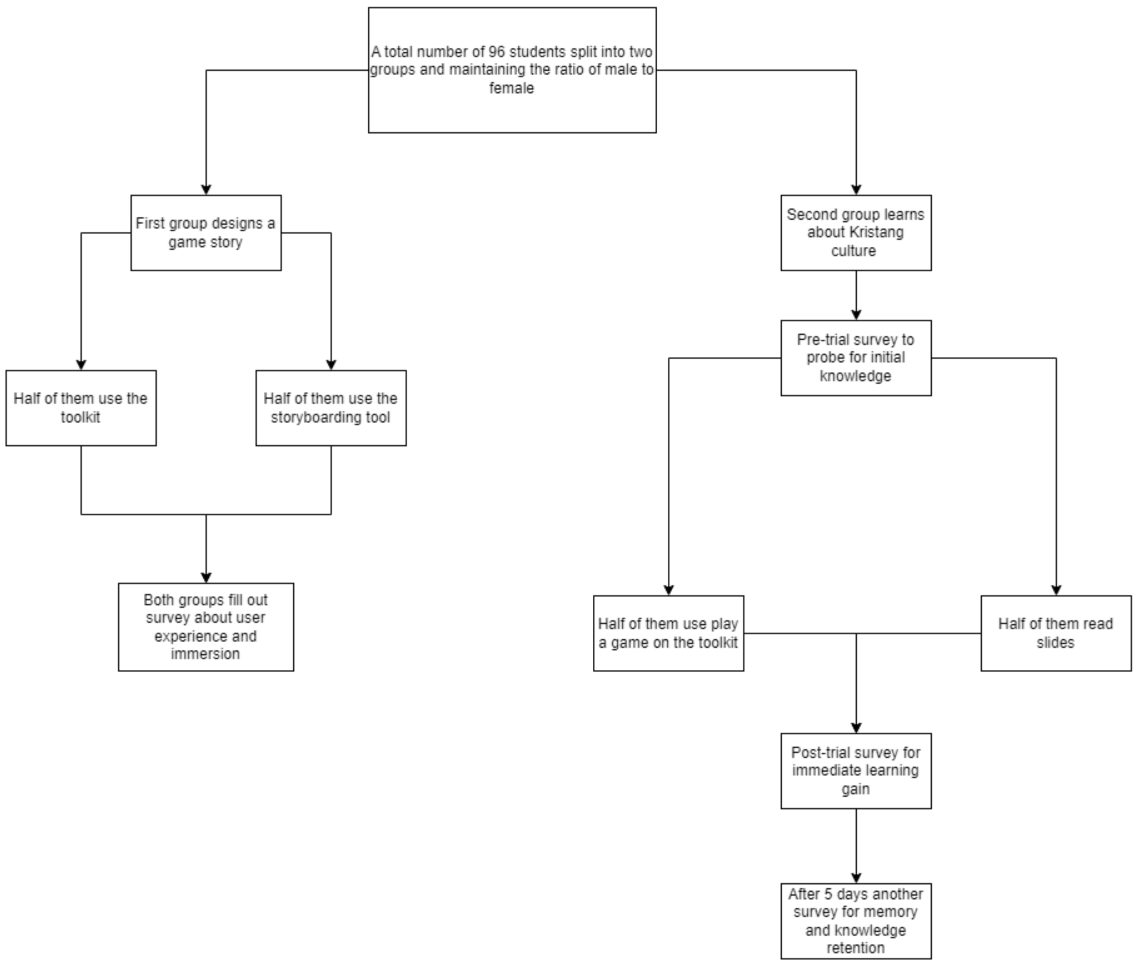

Figure 3.19 Flowchart showing the methodology of the final trial

3.13 Statistical Analysis Techniques

This section discusses the statistical analysis techniques used and the software used to achieve this analysis. Each subsection discusses the methods used and which software was utilized for that specific statistical technique.

3.13.1 Data Management

Data collected from the study participants were stored and organized using Microsoft Excel. Excel was utilized for data entry, cleaning, and initial organization, ensuring that the dataset was prepared for further analysis.

3.13.2 Statistical Analysis

Statistical analysis was conducted using IBM SPSS Statistics version 28.0.0.0. SPSS is a widely used software package for statistical analysis in various fields, including social sciences, education, and psychology. It offers a comprehensive range of tools and techniques for data analysis, making it suitable for analyzing the datasets obtained in this study.

3.13.3 Descriptive Analysis

Descriptive statistics, such as mean, median, standard deviation, and frequency distributions, were computed to summarize the characteristics of the study variables. These statistics provided a clear overview of the central tendency, variability, and distribution of the data.

3.13.4 Inferential Analysis

Inferential statistics were used to draw conclusions and make inferences about the population based on the sample data. Techniques such as analysis of variance (ANOVA), correlation analysis, multivariance analysis, Mann-Whitney U Test, and Chi Square test were employed to test hypotheses, examine relationships between variables, and explore patterns in the data.

3.13.5 Significance Level

A significance level (α) of 0.05 was chosen for hypothesis testing, indicating that results with a p-value less than 0.05 were considered statistically significant. This significance level was selected to balance the risk of Type I and Type II errors while ensuring the reliability of the findings.

3.13.6 Reporting

The results of the statistical analysis were reported using appropriate tables, figures, and narrative descriptions. Key findings, significant relationships, and relevant trends were highlighted to facilitate interpretation and discussion.

3.13.7 Limitations

It's important to acknowledge the limitations of the statistical analysis technique used. While SPSS provides a robust platform for data analysis, the validity and reliability of the results depend on the quality of the data collected and the appropriateness of the statistical methods employed.

3.14 Summary

This chapter explained the research framework used in this research and depicted a diagram explaining the workflow. The population and sampling techniques used in this study to recruit and sample participants were discussed. Moreover, it explained how the requirements would be gathered through different methods, including learning pedagogies and serious games design research, short user trials, evaluating previous work, and interviews. The design guidelines that were drafted based on the requirements gathering step were discussed to give a clear picture of the guidelines that were used to guide the development of the tool.

The hardware that was used in this research was discussed followed by the software necessary to bring this research and this tool to reality, alongside a simple use-case diagram demonstrating the system and the interactions with the different users. In addition to that, a visual storyboard was included to explain how the final tool would be used in a classroom setting and the development of the tool was also discussed, including the designing features, logic features, saving, and loading features. In addition to that, a class diagram was included to give a clear overview of how the structure of the tool looks like.

The measurements instruments design and development were discussed for each of the user trials conducted, followed by a brief overview of the main user trials in the study. Finally, the statistical analysis techniques are discussed. Further analysis of the trials is included in Section 4. The research focused on identifying the research gap through the literature and identifying the lack of 3D serious cultural game making tools, followed by gathering requirements for the proposed solution, and finally conducting different trials to evaluate the proposed solution followed by the research contributions and improvements.

Chapter 4 Results & Analysis

4.1 Introduction

This section will discuss the results and analysis of the interviews conducted with the experts, students, and teachers. Due to the Covid-19 pandemic an extensive first evaluation trial could not be conducted and therefore only the interviews with the experts, students and teachers were conducted online. It also discusses the results of the second evaluation trial conducted on school students who tried the tool after the logic features were implemented and how they managed to design a game scene and add logic to it to make a fully functioning cultural serious game. Finally, it discusses the results from the final user trial which evaluates the usability and immersion of the tool and also the learning impact that the tool has on cultural education, specifically the Kristang culture.

For each of the trials there are a few different analyses explained depending on the type of trial. The different analyses conducted include instrument validation analysis, demographic analysis, descriptive analysis, qualitative analysis, and inferential analysis. As previously mentioned, experts are denoted by an E followed by the participant number, teachers by a T and students by an S. The detailed information about each participant is in APPENDIX A: Interviewee Details and the feedback from the interviews is also incorporated into the final design guidelines in Chapter 5 as a deliverable to benefit future research.

4.2 Interviews (First Evaluation Trial)

4.2.1 Instrument Validation Analysis

The instrument validation for these interviews was conducted to ensure that the data collected accurately reflects the participants' perspectives on the tool's prototype. Given the unstructured nature of the interviews, validation focused on ensuring comprehensive coverage and relevance of the discussion topics. The interviews were designed around three main points: general feedback on the tool, cultural feedback (for cultural experts), and educational feedback (for education participants, both teachers and students). Content validity was ensured by reviewing the interview transcripts to confirm that all relevant aspects of the prototype were discussed. Expert feedback from cultural and educational specialists further validated that the topics were appropriate and comprehensive. Additionally, consistency in feedback was maintained through a thematic analysis of the responses, ensuring reliability. This approach confirmed that the interviews effectively captured meaningful insights aligned with the research objectives.

4.2.2 Demographic Analysis

The demographic characteristics of the eight participants who took part in the interviews are summarized as follows:

Age:

- Participants ranged in age from 20 to 75 years old.
- The majority (3 out of 8) were between 35 and 40 years old.

Gender:

- There were 5 male and 3 female participants, providing a decent gender representation.

Occupation:

Participants included a mix of professionals:

- Two cultural experts, a museum founder and a Kristang community leader.
- Three teachers, of which one is an associate professor, one is an assistant and finally one was a school principal.
- Three education students, including one PhD student.

Education Level:

- Two of the teacher participants had a PhD, and one a bachelor’s in education.
- Two of the student participants were working towards a bachelor’s in education
- One student participant was working towards a PhD in Education.
- One expert had a bachelor’s in philosophy.

- The other expert did not attend higher education, but he is a well-known community activist and leader among the Kristang community and in Malacca in general.

Cultural Background:

Participants represented diverse cultural backgrounds:

- The two expert participants identified as belonging to a minority cultural group relevant to the study.
- Two teacher participants identify as Chinese Malaysians, while the last one is a foreigner.
- The three student participants were all international students, however, of Asian descent.

Relevant Experience:

The participants each had different experience levels and perspectives, which were useful when evaluating the tool:

- The two cultural experts have decades of experience in between them when it comes to preserving the Malaccan culture, and both have participated in numerous events and projects to preserve their culture.
- The three educators are all experienced within the field of education considering it is their main career profession.
- The three student participants included two aspiring participants who wanted to work as teachers when they graduate and provide a fresh perspective on ways to revolutionize the field while one participant was an active researcher in the field of education while pursuing their PhD.

Relating Demographics to the Study:

The diverse age range and balanced gender representation ensured that the feedback reflected a variety of perspectives. The mix of occupations, including cultural experts and educators, provided specialized insights into the cultural and educational relevance of the tool. The education level of participants suggests that they were well-equipped to provide informed and critical feedback. The inclusion of participants from different cultural backgrounds ensured that the cultural relevance of the tool was thoroughly evaluated. The varied level of experience offers a varied and fresh perspective into the tool and provides useful insights for the future of this research.

4.2.3 Qualitative Analysis

The qualitative analysis of the interviews followed a structured process to derive meaningful insights from the transcribed data. The steps included:

1) **Transcription and Familiarization**

The interviews were all recorded and subsequently reviewed multiple times and then all the important and relevant points were transcribed. The transcriptions were then reviewed multiple times to become familiar with the data, noting initial thoughts and patterns.

2) **Categorization**

The transcribed notes and quotes were categorized based on three main themes or categories. Those three categories were general feedback, feedback from a cultural perspective which included the specific cultural perspective from the cultural experts and finally feedback from an educational perspective which included the specific educational perspective from the teachers and students.

3) **Data Interpretation**

The themes were analyzed to interpret the meaning and significance of the feedback. This involved exploring the relationships between different themes and understanding the underlying patterns in the participants' responses.

4) **Reporting:**

The findings were organized and reported, using direct quotes from the interviews to illustrate key themes and provide evidence for the interpretations. The analysis highlighted both commonalities and differences in feedback across the different participant groups.

This qualitative analysis approach ensured a systematic examination of the interview data, allowing for a comprehensive understanding of the participants' perspectives on the tool prototype from general, cultural, and educational viewpoints. The specific details of the interviews with analysis of the feedback are below:

Experts:

Two experts have been interviewed after viewing the initial prototype of the tool developed. Their feedback and suggestions were recorded based on different questions asked. Trying to get requirements from the experts was through asking about their feedback on current features in the tool, their opinion on culture, what are the important aspects of culture that needs to be reserved and what improvements could be made.

After initially viewing the demo of the tool both participants E1, founder of the Bendahari Museum and E2, a Kristang community leader in Malacca, had positive comments to say such as "*I think this is actually a really good way to do, like an activity*" (E1) and "*This is a good approach for the kids"* (E2). On the topic of games developed by the tool, both participants agreed that games speak to the younger generations and therefore are a good means of communication. E1 said "*I think it is a really good way for people to learn about culture. It is a language that speaks to the younger generation. I could see my nephew using it*." And E2 seemed to also agree with this point by first pointing out how the approach really matters with the younger generations by saying "*The approach is very important. They might be interested in language, or re-tracking history*" and then by confirming that games are a good approach for culture by confirming that "*Games are the young people's way of communicating*".

However, having the proper content to deliver is just as important as having a good means of communication. Participant E1 stressed out that the tool needs to be improved to include intangible assets, with accurate historical facts by mentioning that "*The facts need* *to be there. If the objective is just to get them interested, then I think it will work. You just need to make sure that the facts are accurate.*" Both E1 and E2 added that the inclusion of a variety of cultural assets is crucial for content delivery when they said "*You can build the game in terms of language or characters to make it more realistic to teach kids about the different cultural aspects, besides objects. You could have different characters with different backgrounds also, and they can choose these different characters*." (E1) and "*There could be various forms of old photographs*" (E2). Additionally, E2 said it is important to preserve language, stories, how people looked like and more by saying "*We want to preserve the whole thing, meaning, history of the area, and then many interesting stories that happened in that area. How people looked in that area, something that really took place in that area*" and "*The struggle of sticking to the language, which is not easy. Native language speakers are slowly moving on. The use they speak, the way they use some phrases even*" while also pointing out that "*if something is not recorded, it will be forgotten*". Similarly, E1 suggested that there is a problem in passing down information by saying "*One issue is passing on the information from one generation to the next*" and therefore it is important to include information about the assets in the tool by mentioning that "*I think that having some intangible aspects into it will bring more depth to it. As you take audio clips or the buildings, you could have a little bit of the story behind them*".

Speaking about how this tool could be incorporated into education and learning, E1 said that "*Getting it into a classroom depends on the facilitator, a history teacher and an art teacher or a creative writing teacher would probably use it very differently. It would be really interesting to see how they would use it in different ways*.". However, E1 did not limit it to classrooms by mentioning that "*Even outside the classroom, if these students could recreate their own culture in a fun way*" but it should be noted that E1 suggested the tool to not be used alone to teach but as a supporting tool by saying "*I think it's important for people to experience the culture first in person, then reinterpret it in this own way using the toolkit. Having a lesson plan or a virtual recreation, I guess it depends. The (Virtual) Guide can help decide how authentic cultural world can look like. The language that they speak as well. Use language and characters to make the game more realistic*" but E1 stressed that it has to be engaging by saying "*Have an engagement, not make it boring.*

Make it entertaining enough, fun enough to come back and explore more" which could be accomplished by the inclusion of IoT.

Teachers:

Three teachers have been interviewed after viewing the demo and they had very interesting thoughts on what are the advantages of this tool, and how it could be further improved and incorporated into educational settings. As first impressions the three teachers were impressed by the tool and praised it as an interesting choice to teach culture. T1, an education assistant professor, mentioned that "*As a teacher, this could be a very useful tool. I think it would be very interesting to see*" while T2, an education associate professor said "*Given my interest in IoT, new media and gaming as well, it seemed like a very relevant platform to introduce to culture. Computers are the way to go, IoT and games are the way to go, also in terms of learning about culture, etc.*" and finally T3, a school principal, mentioned that "*If you ask the students to learn something from the 17th century, it is not related to them, to them they feel this is the past history why do we need to study it, because it is not in their interest. But if you can bring the content live, to games, perhaps it will help engage the interest of the students*".

T2 had more praises for the tool by saying that "*It is a very advanced kind of design and it would really engage students, young adults, and adults actually. I mean this is fantastic*" and by also mentioning that "*It is very exciting, I can already see how students will respond to this, it will be very well received*". When asked about the first-person feature of designing a level T2 and had T3 had different opinion with T2 saying that "*I think first person is certainly the way to go, you see yourself as moving in this phase and designing it. That also seems to be the way nowadays games are being played. That would be the way to go*" while T3 stated that "*I would not say if it (first-person feature) is useful or useless. I think it depends on how the teachers use it. Even walking could be useful to learning if teachers know how to guide the students*" which shows that proper guidance needs to be given.

Based on that, all three teachers have agreed that proper context and guidance must be involved to use this tool in an education setting like a classroom. T1 stated that "*You* *need a manual; a teacher's guide and you need a manual for the students. The teacher*'s *guide will provide the teacher with the ideas of what is in this toolkit*" while T2 explained that "*Very easily it could be integrated into a history class, and it is obviously in line with the topic of the week or the month, based on the themes that you are doing. I think schools already have these technologies, computers, and things like that. And sort of going by the syllabus, just make it come alive and of course to have sessions to collect data. Very easily incorporating into the syllabus*" and finally T3 agreed with the previous points by saying "*The best way is to work with a teacher, because the teacher will provide the learning content. If you really want to make it for education, then it has to have certain context that would actually draw from the book. To help the students understand the culture that is derived from the book*" and also that "*You want to bring the textbook live with your gamification concept*".

As an addition to that T1 expressed that "*The first thing the students would need to do is the storyline. As a teacher, the first thing I would ask them to do would be to ask them to create a storyline*" which T3 also agreed in a way by mentioning that "*We need to understand the history first, before we can come up with the characters, the setting. There must be a context first, before we can actually design the game*". When asked about improvements to the tool T2 suggested the concept of interculturalism where people from different backgrounds would work together to achieve a common goal. T2 said that "*To include interculturalism, you need to group them up. Get them to talk about each other's cultures. Cultural immersion will help with this notion of interculturality. You sort of put yourself in the others shoe and learn about it in order to build something*". Moreover, T2 suggested adding conversations as audio clips, giving the games elements of call to action, or including VR to make it more immersive. T3 suggested that the assets being similar to actual cultural artifacts might arouse the student's interest. Finally, T1 questioned that "*Will I be able to create different scenes? Let us say I want an island, a scene of a village? Can the children create their own coconut trees? Ships?*" Furthermore, T1 questioned the accessibility of the toolkit asking "*Where do I got to access this? A website? Do I need to download an app?*".

T3 expressed how learning culture is important by mentioning that "*It is important for kids to learn about culture, to help students open up their minds. To accept different and to also understand the variety of different cultures. From there you can instill values in them as well. You should be more open-minded because you are not living in your world. Look at how other people dress, eat, think and from there what can you learn from them. I think learning culture is very important and I think they should be exposed to more than culture and not just be confined to one type of culture*".

Finally, T1 explained what learning pedagogies are involved in this tool by saying "*I could see stimulating creativity, and this is where I would tell the students to create a storyline. In the storyline it would allow the students to create a technique for their task, as a first step before going to the next scene. It would definitely stimulate their creativity and the way they respond to different cultures. In the storyline it would allow the students to create a technique for their task, as a first step before going to the next scene. It would definitely stimulate their creativity and the way they respond to different cultures*". Moreover, T1 also mentioned that the toolkit might also be used to teach other things like geography or mathematics by saying "*I see a couple of things being integrated here, geography and language and arts skill, critical thinking, reading and writing and that even mathematics. Talking about kilograms and pounds. Or to convert from one unit to another because different cultures use different units, even currencies. I could see mathematics being included in the missions. The landscape or the location, they could learn about the different islands, continents*".

Students:

A total of three education students were interviewed after they watched the demo of the toolkit. Their views on the tool were interesting given that they are the educators of the future and have been around modern technology for longer.

S1, a first-year education student, was quick to point out that "*I think it is very immersive, I really like the idea of the designer being involved in the process by walking around. I really like the customizable aspect to it, that you can change the colors, the rotation*" while S2, a first-year education student, mentioned that "*The interface is very* *familiar, for me at least it was quite easy to understand and I would be able to navigate it quite well. And I would imagine that anyone familiar to any degree with some of the games would be able to navigate quite easily as well*" and finally S3, a postgraduate education student, commented by saying "*After I understand what you are going to do, I think this toolkit is very good, because I think it is quite technology friendly. Whoever has been technology friendly, they will think that this toolkit is very easy. That is because of including different game settings, and some could figure about education and strategies in your games because the teachers can do it and the students can also contribute to do it and can modify to meet different learning objectives*". S3 also mentioned that "*Because the toolkit is individualized and personalized setting, it could encourage the learner to input their own engagement into the subject of pitching and learning process*" and "*What I really like is that it is quite different from other games I have played. You paid very careful attention to the objects in your game. The angles and the shadows are quite realistic. And I think it could create immersion for the student. This kind of design is very interesting and could be used in different ways*".

Each of the three students had improvements to mention about the tool beginning with S1 mentioning "*I do think that if you can add like a quest list, that the student has to achieve. Kind of acting like a guideline, like a mission, build your house, build the area around your house*" and "*I think the cursor in the middle of the screen is a little bit too big*" while S2 mentioned "*Is there a way to embed videos or pictures, for example, if you are talking a character or what not, then the conversation would lead to watching a video about what they are talking about*" and finally S3 suggested "*I prefer if the student can choose different setting. I would like to choose the character names, put a logo. Make it more personalized*" and "*Add animals, cows, or sheep so that the student can learn about the animals in different cultures*".

S1 and S2 seemed to agree that the toolkit could be used outside classrooms and for other applications other than culture when S1 said "*I think this could be used independently, not just in classrooms. I think each student could take this home and create something to share with the rest of their friends. I think it would be best utilized individually, outside the classroom*" stating that computer resources might be limited in classrooms while S2 said "*I think it could be a lot broader than just culture. I think I would enjoy making levels quite a bit and making my friends play them. I think it is quite an interesting idea and not just for teaching culture in classrooms*".

S3 added that social constructivism was used in the tool when asked about which learning pedagogies are used, by mentioning "*Social constructivism, because the teachers assign a task to a lot of students, that way the students can interact and work together for social interaction and encourage their constructivism*" and also suggested active learning was being used since teachers could assign tasks from a low level and increment the difficulty to a higher level as the student progresses through the learning progress, which can be seen as a form of scaffolding technique.

4.3 Second Evaluation Trial

4.3.1 Overview

The second evaluation trial took place after the logic features were implemented. At this point the users can use the tool to design a game scene and add logic to it to make a fully functioning game. The focus of the trial was to evaluate how the users are able to design their games and their experience while playing games designed by the tool. Different features were asked about like the movements, the graphical user interface, the saving, etc. The study involved 22 school students aged between 11 and 13 of which 18 were males and 4 were females.

They were each introduced to the Kristang culture of Malacca very briefly through oral presentation to give them a quick idea about the culture they were about to make a game about. The tool included an archive feature that included famous stories about the Kristang culture that they could refer to for help in creating games. Each participant spent around 10 to 20 minutes designing a level and saving their work and created a story of their own based on the materials they have been presented before and through the archive feature in the toolkit.

To keep the experience consistent, they were all asked to play the same demo game created using the tool to evaluate the game playing aspect of the tool. The participants were supervised the entire time in case a software bug arose, which did occur a few times but was quickly rectified. Based on their experience each participant answered a survey consisting of 14 questions with each question being a Likert scale question ranging from 1 to 5 with 1 being the most negative and 5 being the most positive. The questions of the survey are presented in APPENDIX B: Questionnaire 3.

4.3.2 Instrument Validation Analysis

To ensure the reliability of the questionnaire, an internal consistency analysis using Cronbach's Alpha in SPSS was conducted. By analyzing the responses from the Likert scale items, Cronbach's Alpha coefficient was calculated, which measures the degree to which items within a scale are consistent in their measurement of the underlying construct. A Cronbach's Alpha value of 0.893 indicates acceptable reliability, confirming that the instrument consistently measures the intended construct.

Reliability Statistics

Cronbach's Alpha	N of Items
.893	14

Figure 4.1 The reliability Cronbach's Alpha value for the second user trial questionnaire

To establish discriminant validity for the instrument used in the study, an Exploratory Factor Analysis (EFA) was conducted following standard procedures. Initially, the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's test of sphericity were computed to assess the suitability of the data for factor analysis. The KMO measure was found to be 0.731, indicating good sampling adequacy, while Bartlett's test was significant ($p < 0.001$), confirming that the correlations between items were appropriate for factor analysis as seen in Fig 4.2. During the preliminary analysis, several questions exhibiting high inter-item correlations (above 0.9) were identified and removed to address potential multicollinearity and ensure a clearer factor structure.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.731
Bartlett's Test of Sphericity	Approx. Chi-Square	126.826
	df	36
	Sig.	<.001

Figure 4.2 The KMO and Bartlett's Test results for the second user trial questionnaire

After refining the dataset, the rotated component matrix revealed three distinct components as seen in Fig 4.3. However, most of the questionnaire was related to different user experience aspects, and despite the distinct components they still all fall under user experience which is the main construct identified in Section 3.12.2. Component 1 had questions related more to the usefulness of the features, namely Questions 5,6,7,8,9,10, and 14 while Component 2 had questions more heavily loaded on it indicating more Opinion-Based questions namely Questions 1,2,3, and 13 and finally Component 3 was focused on ease of use namely Questions 4 and 11. There was room for improvement in structuring this questionnaire as the language used in the questions might have caused overlaps in the Components since some other questions also indicated ease of use but loaded more on Component 1 which relates to the usefulness of the feature. In addition to that, since some questions were removed for factor analysis due to their high inter-item correlations, it indicates that the survey could have been better designed and the questions better worded, however the excluded questions from the factor analysis were mentioned above under which Component would suit them best.

Rotated Component Matrix[a]

	Component 1	Component 2	Component 3
Q1	.411	.797	.072
Q4	.026	-.201	.887
Q5	.881	.218	.008
Q7	.928	.045	-.043
Q8	.929	-.010	-.001
Q9	.914	.004	-.128
Q12	.193	-.458	-.644
Q13	-.017	.875	-.088
Q14	.895	.152	-.054

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.

Figure 4.3 The rotated component matrix for the second user trial questionnaire

4.3.3 Demographic Analysis

The demographic characteristics of the 22 participants who took part in the second user trial are summarized as follows:

Age:

- Participants ranged in age from 11 to 13 years old.
- The majority (8 out of 22) were 11 years old, with an equal number (8 out of 22) being 12 years old, and the remaining 6 participants were 13 years old.

Gender:

- There were 18 male and 4 female participants, providing a predominantly male representation.

Education Level:

- All participants were middle school students.

- They were proficient in speaking and writing English, ensuring clear communication and understanding during the trial.

Cultural Background:

- All participants were of South Asian descent. Given that the trial focused on the Kristang culture, their non-Malaysian and non-Southeast Asian background likely meant they had limited prior knowledge of Kristang culture, enhancing the trial's objective to gauge fresh perspectives.

Relating Demographics to the Study:

The age range of participants, predominantly comprising 11- and 12-year-olds, ensured that feedback was reflective of young adolescents, the target demographic for many educational tools. Although the gender representation was skewed towards males, it still provided a basic level of diversity in gender perspectives. The participants' South Asian background was particularly beneficial for the study on Kristang culture as it allowed the trial to capture the perceptions and understanding of individuals unfamiliar with this cultural context. This unfamiliarity is valuable for assessing user experience while using the tool involving assets and features about the Kristang culture. Being middle school students proficient in English, the participants were well-suited to engage with the material and provide insightful feedback on its clarity, accessibility, and educational value. The diverse age range, combined with their cultural and educational background, ensured that the feedback was comprehensive and relevant, providing valuable feedback on the state of the tool.

4.3.4 Descriptive Analysis

The results of this evaluation study provided valuable insights into the tool's performance and identified areas for improvement. The majority of participants (86.36%, N = 19) found it easy to navigate the tool and control their camera, which is unsurprising given the tool's use of a first-person view controller, common in video games ($\tilde{x}$ = 4.50, $\bar{x}$ = 4.36, *mode* = 5, *range* = 2, s^2 = 0.528, *s* = 0.727, *min* = 3, *max* = 5). Half of the participants (50%) widely accepted the GUI of the tool, while 8 participants (36.36%) rated it above average, indicating that the GUI could be made more visually pleasing and user-friendly ($\tilde{x}$ = 3.50, $\bar{x}$ = 3.36, *mode* = 4, *range* = 2, s^2 = 0.528, *s* = 0.727, *min* = 2, *max* = 4).

Regarding the design aspect of the tool, it is crucial that users have enough workspace. Twelve participants (55.55%) agreed that the space was sufficient, while 7 participants (31.82%) rated it a 3, slightly above average ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.68, *mode* = 3, *range* = 3, s^2 = 1.084, *s* = 1.041, *min* = 2, *max* = 5). Another important aspect of the design process is the ease of using controls. Thirteen participants (59.10%) found the controls easy, but the rest did not fare as well, indicating that the controls need further simplification ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.64, *mode* = 5, *range* = 3, s^2 = 1.576, *s* = 1.255, *min* = 1, *max* = 5).

The saving and loading features were effective for the majority, with 19 participants (86.36%) finding it easy to save and load their work ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.64, *mode* = 5, *range* = 2, s^2 = 0.513, *s* = 0.716, *min* = 3, *max* = 5). Seventeen participants (77.27%) found it easy to use and create game logic quests ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.00, *mode* = 4, *range* = 2, s^2 = 0.476, *s* = 0.690, *min* = 3, *max* = 5). Additionally, 19 participants (86.36%) found it easy to test their game by switching between design mode and play mode ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.18, *mode* = 5, *range* = 2, s^2 = 0.632, *s* = 0.795, *min* = 3, *max* = 5).

To assist users in creating their stories, a story archive was included in the tool, with 16 participants (72.73%) finding it useful ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.91, *mode* = 4, *range* = 2, s^2 = 0.468, *s* = 0.684, *min* = 3, *max* = 5). A similar number of participants found the GUI of the games pleasant, an improvement compared to the GUI for designing games ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.00, *mode* = 4, *range* = 2, s^2 = 0.476, *s* = 0.690, *min* = 3, *max* = 5). The built-in quest system, which simplifies many development aspects, was found to be easy to use by 14 participants (63.64%), who felt it provided sufficient guidance ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.64, *mode* = 4, *range* = 3, s^2 = 1.195, *s* = 1.093, *min* = 2, *max* = 5).

During the game-playing phase, the controls were user-friendly, with 17 participants (77.27%) finding them easy to use ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.00, *mode* = 4, *range* = 2, s^2 = 0.476, *s* = 0.690, *min* = 3, *max* = 5). The most significant negative feedback concerned the lack of objects for game design, as 14 participants (63.64%) noted this issue ($\tilde{x}$ = 2.00, $\bar{x}$ = 2.36, *mode* = 2, *range* = 1, s^2 = 0.242, *s* = 0.492, *min* = 2, *max* = 3). Solving this would require hiring a professional 3D artist to design objects for the tool, which could be feasible with a larger budget or industry adoption. Furthermore, the rise in generative methods might provide a feasible solution of generating 3D models based on prompts by utilising a state-of-the-art generative AI model.

As the tool was still under development during this trial, not all quest type options were available. This was reflected in the scores for creating quests, with 8 participants (36.36%) dissatisfied with the options, 9 participants (40.91%) rating it a 3 out of 5, and only 5 participants (22.73%) finding it acceptable ($\tilde{x}$ = 3.00, $\bar{x}$ = 2.82, *mode* = 3, *range* = 3, s^2 = 0.727, *s* = 0.853, *min* = 1, *max* = 4). This indicated a need for more quest types and overall system improvements.

Despite feedback about the limited assets and quest creation options, users saw the tool's potential. Sixteen participants (72.72%) agreed that the tool has the potential to teach others about the Kristang culture or any other culture, provided it includes enough assets ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.91, *mode* = 4, *range* = 3, s^2 = 0.658, *s* = 0.811, *min* = 2, *max* = 5). Fig 4.4 and Fig 4.5 shows the descriptive statistics mentioned above and Fig 4.6 shows a stacked bar chart with the user responses. Each colour in the chart represents one of the five numbers on the Likert scale starting from 1 to 5. Light blue represents 1, orange represents 2, grey represents 3, yellow represents 4 and blue represents 5.

Descriptive Analysis for the second main user trial

		Q1	Q2	Q3	Q4	Q5	Q6	Q7
N	Valid	22	22	22	22	22	22	22
	Missing	0	0	0	0	0	0	0
Mean		4.36	3.36	3.68	3.64	4.32	4.00	4.18
Median		4.50	3.50	4.00	4.00	4.00	4.00	4.00
Mode		5	4	3	5	5	4	5
Std. Deviation		.727	.727	1.041	1.255	.716	.690	.795
Variance		.528	.528	1.084	1.576	.513	.476	.632
Range		2	2	3	4	2	2	2
Minimum		3	2	2	1	3	3	3
Maximum		5	4	5	5	5	5	5

Figure 4.4 The descriptive analysis of the second main user evaluation trial (Part 1)

Descriptive Analysis for the second main user trial								
		Q8	Q9	Q10	Q11	Q12	Q13	Q14
N	Valid	22	22	22	22	22	22	22
	Missing	0	0	0	0	0	0	0
Mean		3.91	4.00	3.64	4.00	2.36	2.82	3.91
Median		4.00	4.00	4.00	4.00	2.00	3.00	4.00
Mode		4	4	4	4	2	3	4
Std. Deviation		.684	.690	1.093	.690	.492	.853	.811
Variance		.468	.476	1.195	.476	.242	.727	.658
Range		2	2	3	2	1	3	3
Minimum		3	3	2	3	2	1	2
Maximum		5	5	5	5	3	4	5

Figure 4.5 The descriptive analysis of the second main user trial (Part 2)

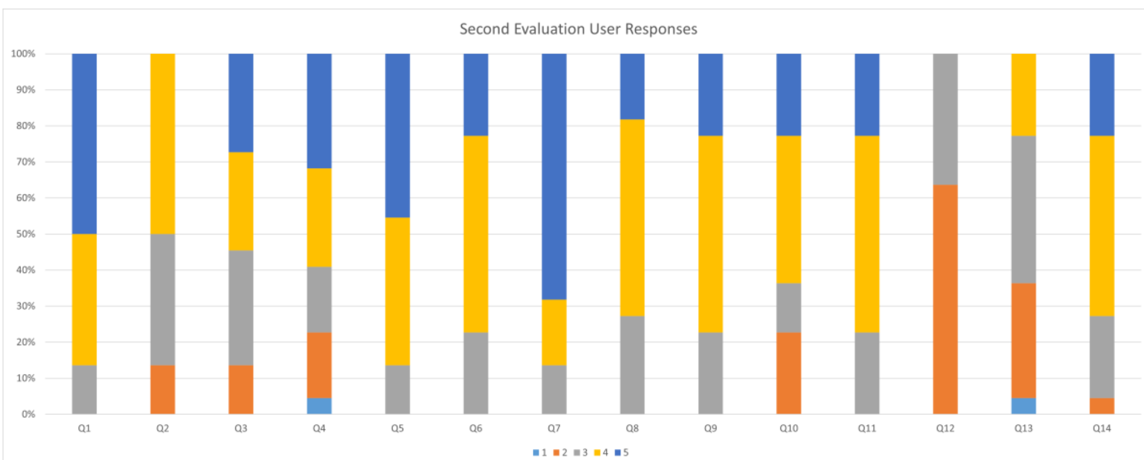

Figure 4.6 The user responses from the second main user evaluation trial

4.4 Third and Final Evaluation Trial

4.4.1 Overview

The third and final evaluation trial consisted of 96 middle school students aged between 12 and 13 years old. Out of the participants **66.67%** were males (**n=64**) while **33.33%** (**n=32**) were females. **83.33%** of the participants were 12 years old (**n=80**) and the other **16.67%** (**n=16**) were 13 years old. The main aim of this trial was to evaluate the two main uses of the tool, namely designing a cultural serious game about the Kristang culture and playing a designed game.

To keep things consistent the participants were divided into two groups, so that no participant performed both actions as this would interfere with the results. All of the participants have never used this tool before, so their experiences are all for the first time. The participants also had no previous knowledge about the Kristang culture as they were not Malaysian students, and therefore it was assumed they are not familiar with that culture. The participants were split equally, while maintaining the ratio of males to females, so each group had 32 males and 16 females.

There were two questionnaires developed for this trial, one measuring the user experience while the participants are designing a serious Kristang cultural game using the tool and the other was a knowledge-based questionnaire asking the participants questions to test their knowledge about the Kristang culture. Both of these questionnaires can be viewed in APPENDIX B: Questionnaire 4a and 4b. Each group was further split into a test group and a control group to measure the impact of the tool more accurately compared to a traditional method. For the game and story designing group, the control group used a digital storyboarding tool as their method to create and design a game story while for the cultural learning impact group the control group learned the same knowledge conveyed in the serious cultural game designed by the tool using a traditional passive learning way of reading from slides.

4.4.2 Instrument Validation Analysis

For the questionnaire measuring the user experience a reliability analysis was conducted using all the questions related to user experience, which meant that questions like Q1, Q2, Q7, and Q8 were not included as they are not measuring the same underlying construct. The internal consistency of the scale questions as assessed by Cronbach's alpha, was found to be 0.739. This indicates a moderate to strong level of internal consistency among the included items, suggesting that the items are measuring a common underlying construct in a reasonably consistent manner. Fig 4.7 shows the reliability analysis result.

Reliability Statistics	
Cronbach's Alpha	N of Items
.739	16

Figure 4.7 The reliability analysis result for the user experience questionnaire

Furthermore, to conduct discriminate validity for the instrument an EFA was carried out to determine the components in the questionnaire. To determine the data suitability for factor analysis the KMO was calculated alongside Bartlett's test of sphericity. After excluding a few questions due to high inter-item correlations, a KMO value of 0.715 was obtained which shows a good sampling adequacy and a significant Bartlett's score which had a p value under 0.001, making the data suitable for factor analysis as seen in Fig 4.8.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.715
Bartlett's Test of Sphericity	Approx. Chi-Square	148.111
	df	55
	Sig.	<.001

Figure 4.8 The KMO and Bartlett's score for the user experience and immersion group in the third main user trial

After obtaining the rotated component matrix it can be seen that there are four main components within the questionnaire. Based on the analysis of the matrix it can be concluded that Questions 5, 9, 10, 15, and 16 belong to Component 1 which would translate to construct of immersion, especially cultural immersion. Questions 4, and 17 belong to Component 2 which leans more towards user friendliness while Component 3 leans more towards ease of use via Questions like 3, 12 and 13.

Finally, Component 4 leans more towards a construct of users feeling rewarded with the experience and interface with Questions 6, 18, 19 and 20 falling under that category. Question 1, 7 and 8 were not under any of those Components as they were not specifically targeting anything related to user experience or immersion but were included to understand the user behavior better and to try to understand if there were other conclusions to be drawn from those other factors while Question 2 was related to which tool they used. While the results from this analysis differ slightly from the constructs set forth in Section 3.11.3 they do not nullify them. The statistical results group together Questions like 18, 19, and 20 which were intended under user immersion as part of the research established by (O'Brien, et al., 2018). However, it is important to realize the limitation of the statistical methods when the sample size is not too big which could affect the accuracy of the scores. Fig 4.9 shows the rotated component matrix.

Rotated Component Matrix[a]

	Component			
	1	2	3	4
Q4	.133	.850	-.066	-.060
Q5	.746	.390	-.135	-.090
Q6	-.032	-.096	-.135	.838
Q9	.851	.014	.118	.012
Q10	.721	.218	-.167	.160
Q11	.760	.161	-.030	.253
Q12	-.114	-.260	.821	-.136
Q13	.137	.196	.793	.079
Q15	.604	.094	.200	-.096
Q17	.307	.744	.052	.223
Q19	.166	.365	.147	.607

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Figure 4.9 The rotated component matrix for the user experience and immersion group in the third main user trial

For the knowledge-based questionnaire used for the second group in this trial to measure the learning impact from playing a serious cultural game about the Kristang culture compared to reviewing the same information from slides, it was not possible to conduct a reliability analysis in the same fashion since the question format was in an MCQs format with string answers. The metrics used to determine the efficiency of the learning process were all based on existing research conducted by the main researcher of this work and the three learning metrics used namely learning gain, memory retention, and knowledge retention are all defined and explained in (Sanzana, et al., 2021). However, this questionnaire was designed in a way to ask questions about the Kristang culture starting from easy questions and ending with harder questions. Easy questions were ones that included aspects about the culture like location and religion while harder questions included remembering information like years which could be harder to remember. The questions were verified with the main supervisor of this research prior to usage in the trial.

4.4.3 Demographic Analysis

The demographic characteristics of the 96 participants who took part in the third user trial are summarized as follows:

Age:

- Participants ranged in age from 12 to 13 years old.
- The majority (80 out of 96) were 12 years old, while the rest (16 out of 96) were 13 years old.

Gender:

- There were 64 male and 32 female participants, providing a predominantly male representation.

Education Level:

- All participants were middle school students.
- They were proficient in speaking and writing English, ensuring clear communication and understanding during the trial.

Cultural Background:

All participants were of South Asian descent. Given that the trial focused on the Kristang culture, their non-Malaysian and non-Southeast Asian background likely meant they had limited prior knowledge of Kristang culture, enhancing the trial's objective to gauge fresh perspectives.

Relating Demographics to the Study:

The age range of participants, predominantly 12 years old with a minority of 13 years old reflects a suitable age of young adolescents, the target demographic for many educational tools. Although the gender representation was skewed towards males, it still provided a basic level of diversity in gender perspectives. The participants' South Asian background was particularly beneficial for the study on Kristang culture as it allowed the trial to capture the perceptions and understanding of individuals unfamiliar with this cultural context. This unfamiliarity is valuable for assessing user experience while using the tool involving assets and features about the Kristang culture. Being middle school students proficient in English, the participants were well-suited to engage with the material and provide insightful feedback on its clarity, accessibility, and educational value. The suitable age range, combined with their cultural and educational background, ensured that the feedback was comprehensive and relevant, providing valuable feedback on the state of the tool.

4.4.4 Descriptive Analysis

The first key aspect of the tool being evaluated is its user experience and immersion when using the tool to design a game story, however, there needs to be a control group to compare against to truly evaluate the tool. The task that the participants had to do was to design a game story based on some reading material given to them. They were free to create any story that encompasses some elements of the material given to them.

Since the tool is a maker tool that allows creating 3D serious cultural games, a control method that creates 2D stories was chosen, which is storyboarding. A popular storyboarding website (Storyboardthat.com) was used as it is easy to use and has a big collection of assets to use. To prevent the users using the storyboarding tool from having any limitations, the paid version of the storyboarding tool was used so that they have access to more than 5,000 customizable images and millions of photos.

For Q1 the males in the test group rated an average score of **4.75** while the females rated **3.00**, with a combined total of **4.17** ($\tilde{x}$ = 5.00, $\bar{x}$ = 4.17, *mode* = 5, *range* = 4, s^2 = 1.188, *s* = 1.090, *min* = 1, *max* = 5). The males in the control group rated an average score of **4.63** while the females scored **2.38**, with a combined total of **3.88** ($\tilde{x}$ = 4.50, $\bar{x}$ = 3.88, *mode* = 5, *range* = 4, s^2 = 1.679, *s* = 1.296, *min* = 1, *max* = 5). This indicated that males are more familiar with video games in both groups. For Q3, the males in the test group rated an average of **3.81** while the females rated **3.75**, with a combined total of **3.79** ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.79, *mode* = 4, *range* = 3, s^2 = 0.607, *s* = 0.779, *min* = 2, *max* = 5). The control group males rated an average of **3.06**, while the females rated **3.63** with a combined total of **3.25** ($\tilde{x}$ = 3.00, $\bar{x}$ = 3.25, *mode* = 3, *range* = 3, s^2 = 0.543, *s* = 0.737, *min* = 2, *max* = 5). Based on these results, the tool was slightly easier to use compared to the storyboard.

For Q4 both the males and females in the test group rated an average score of **3.63** ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.63, *mode* = 4, *range* = 3, s^2 = 0.418, *s* = 0.647, *min* = 2, *max* = 5) with a combined average score of the same value. The males in the control group rated an average score **2.94** while the females rated an average score of **3.50** with a combined average of **3.13** ($\tilde{x}$ = 3.00, $\bar{x}$ = 3.13, *mode* = 3, *range* = 3, s^2 = 0.549, *s* = 0.741, *min* = 2, *max* = 5) indicating that it was easier to translate ideas into a story using the tool. For Q5 both the males and females in the test group rated an average score of **4.63** ($\tilde{x}$ = 4.25, $\bar{x}$ = 4.63, *mode* = 5, *range* = 1, s^2 = 0.245, *s* = 0.495, *min* = 4, *max* = 5) while the males in the control group rated an average of **2.44** and the females an average of **2.75** with a combined average of **2.54** ($\tilde{x}$ = 3.00, $\bar{x}$ = 2.54, *mode* = 3, *range* = 3, s^2 = 0.433, *s* = 0.658, *min* = 1, *max* = 4), indicating a big difference in how the tool was much better in expressing the Kristang culture, which was also expected considering how the toolkit had the Kristang culture in its core elements, while the storyboard had general assets.

When it comes to rating the user interface in Q6 both the groups had a combined average score of **4.25** ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.25, *mode* = 4, *range* = 2, s^2 = 0.457, *s* = 0.676, *min* = 2, *max* = 5, ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.25, *mode* = 4, *range* = 2, s^2 = 0.370, *s* = 0.608, *min* = 3, *max* = 5)) indicating overall satisfaction with both user interfaces. The test group had **1** male ask the researcher for help during the trial while **2** females also asked for help. This was less compared to the control group where only **1** male asked. The time given was mostly sufficient for everyone except **1** male participant in the test group. Overall, while more participants needed help using the tool and also more time, the differences in number are very minor and given that the tool is more complex to use due to the game mechanics compared to the drag-and-drop mechanic in the storyboard, the difference is considered very minimal.

For the questions about immersion beginning with Q9, the total average of the test group was **4.00** ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.00, *mode* = 4, *range* = 2, s^2 = 0.435, *s* = 0.659, *min* = 3, *max* = 5) and the control group was **2.75** ($\tilde{x}$ = 3.00, $\bar{x}$ = 2.75, *mode* = 3, *range* = 2, s^2 = 0.475, *s* = 0.676, *min* = 2, *max* = 4), indicating more immersion with the tool. Q10 had a noticeable difference as well as the average rating for the test group was **3.71** ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.71, *mode* = 3, *range* = 2, s^2 = 0.563, *s* = 0.751, *min* = 3, *max* = 5) while the control group was **2.42** ($\tilde{x}$ = 2.00, $\bar{x}$ = 2.42, *mode* = 2, *range* = 3, s^2 = 0.428, *s* = 0.654, *min* = 1, *max* = 4). Q11 had an average rating of **3.63** ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.63, *mode* = 4, *range* = 3, s^2 = 0.418, *s* = 0.647, *min* = 2, *max* = 5) for the test group while the control group was **2.38** ($\tilde{x}$ = 2.00, $\bar{x}$ = 2.38, *mode* = 2, *range* = 3, s^2 = 0.505, *s* = 0.711, *min* = 1, *max* = 4), which indicates that the tool was more immersive.

Q12, Q13, and Q14 were negative sentences and the feedback from both groups was low rating considering they mostly disagree with those statements. Head-to-head comparison shows that the test group had an average rating of **1.71** ($\tilde{x}$ = 2.00, $\bar{x}$ = 1.71, *mode* = 1, *range* = 2, s^2 = 0.563, *s* = 0.751, *min* = 1, *max* = 3) **1.79** ($\tilde{x}$ = 2.00, $\bar{x}$ = 1.79, *mode* = 2, *range* = 2, s^2 = 0.520, *s* = 0.721, *min* = 1, *max* = 3), and **1.17** ($\tilde{x}$ = 1.00, $\bar{x}$ = 1.17, *mode* = 1, *range* = 1, s^2 = 0.145, *s* = 0.381, *min* = 1, *max* = 3) for Q12, Q13 and Q14 respectively. As for the control group they rated an average rating of **2.13** ($\tilde{x}$ = 2.00, $\bar{x}$ = 2.13, *mode* = 2, *range* = 2, s^2 = 0.462, *s* = 0.680, *min* = 1, *max* = 3), **1.54** ($\tilde{x}$ = 1.50, $\bar{x}$ = 1.54, *mode* = 1, *range* = 2, s^2 = 0.346, *s* = 0.588, *min* = 1, *max* = 3), and **1.08** ($\tilde{x}$ = 1.00, $\bar{x}$ = 1.08, *mode* = 1, *range* = 1, s^2 = 0.080, *s* = 0.282, *min* = 1, *max* = 2) respectively.

Q15, Q16, and Q17 were focused on the visual appearance of the tool used and the average ratings from the test group were **4.46** ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.46, *mode* = 4, *range* = 1, s^2 = 0.259, *s* = 0.509, *min* = 4, *max* = 5), **4.58** ($\tilde{x}$ = 5.00, $\bar{x}$ = 4.58, *mode* = 5, *range* = 1, s^2 = 0.254, *s* = 0.504, *min* = 4, *max* = 5), and **4.25** ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.25, *mode* = 4, *range* = 2, s^2 = 0.370, *s* = 0.608, *min* = 3, *max* = 5) while the control group had an average rating of **3.92** ($\tilde{x}$ = 4.00, $\bar{x}$ = 3.92, *mode* = 4, *range* = 3, s^2 = 0.688, *s* = 0.830, *min* = 2, *max* = 5), **4.21** ($\tilde{x}$

= 4.00, $\bar{x}$ = 4.21, *mode* = 3, *range* = 2, s^2 = 0.259, *s* = 0.509, *min* = 3, *max* = 5), and **3.54** ($\tilde{x}$ = 3.50, $\bar{x}$ = 3.54, *mode* = 3, *range* = 2, s^2 = 0.346, *s* = 0.588, *min* = 3, *max* = 4) respectively. Overall, it shows that the test group had a more appealing tool than the control group.

Finally, Q18, Q19, and Q20 focus on whether the participants found this experience worthwhile, rewarding, and interesting. The test group rated an average score of **4.50** ($\tilde{x}$ = 4.50, $\bar{x}$ = 4.50, *mode* = 4, *range* = 1, s^2 = 0.261, *s* = 0.511, *min* = 4, *max* = 5), **4.63** ($\tilde{x}$ = 5.00, $\bar{x}$ = 4.63, *mode* = 5, *range* = 1, s^2 = 0.245, *s* = 0.495, *min* = 4, *max* = 5), **4.79** ($\tilde{x}$ = 5.00, $\bar{x}$ = 4.79, *mode* = 5, *range* = 1, s^2 = 0.172, *s* = 0.415, *min* = 4, *max* = 5) while the control group rated an average score of **4.42** ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.42, *mode* = 4, *range* = 1, s^2 = 0.254, *s* = 0.504, *min* = 4, *max* = 5), **4.29** ($\tilde{x}$ = 4.00, $\bar{x}$ = 4.29, *mode* = 4, *range* = 1, s^2 = 0.216, *s* = 0.464, *min* = 4, *max* = 5), and **4.88** ($\tilde{x}$ = 5.00, $\bar{x}$ = 4.88, *mode* = 5, *range* = 1, s^2 = 0.114, *s* = 0.338, *min* = 5, *max* = 5) which shows the tool is slightly better in Q18 and Q19 but slightly behind on Q20. Figures 4.10 and 4.11 show the descriptive statistics for the test group while Figures 4.13 and 4.14 show the descriptive statistics for the control group. Finally, Figures 4.16 and 4.17 show the descriptive statistics of both test and control groups combined just for reference.

Descriptive Analysis for the user experience and immersion group (Test Group)

		Q1	Q3	Q4	Q5	Q6	Q9	Q10
N	Valid	24	24	24	24	24	24	24
	Missing	0	0	0	0	0	0	0
Mean		4.17	3.79	3.63	4.63	4.25	4.00	3.71
Median		5.00	4.00	4.00	5.00	4.00	4.00	4.00
Mode		5	4	4	5	4	4	3
Std. Deviation		1.090	.779	.647	.495	.676	.659	.751
Variance		1.188	.607	.418	.245	.457	.435	.563
Range		4	3	3	1	2	2	2
Minimum		1	2	2	4	3	3	3
Maximum		5	5	5	5	5	5	5

Figure 4.10 The descriptive analysis for the test group (Part 1)

Descriptive Analysis for the user experience and immersion group (Test Group)

		Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
N	Valid	24	24	24	24	24	24	24	24	24	24
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		3.63	1.71	1.79	1.17	4.46	4.58	4.25	4.50	4.63	4.79
Median		4.00	2.00	2.00	1.00	4.00	5.00	4.00	4.50	5.00	5.00
Mode		4	1	2	1	4	5	4	4[a]	5	5
Std. Deviation		.647	.751	.721	.381	.509	.504	.608	.511	.495	.415
Variance		.418	.563	.520	.145	.259	.254	.370	.261	.245	.172
Range		3	2	2	1	1	1	2	1	1	1
Minimum		2	1	1	1	4	4	3	4	4	4
Maximum		5	3	3	2	5	5	5	5	5	5

a. Multiple modes exist. The smallest value is shown

Figure 4.11 The descriptive analysis for the test group (Part 2)

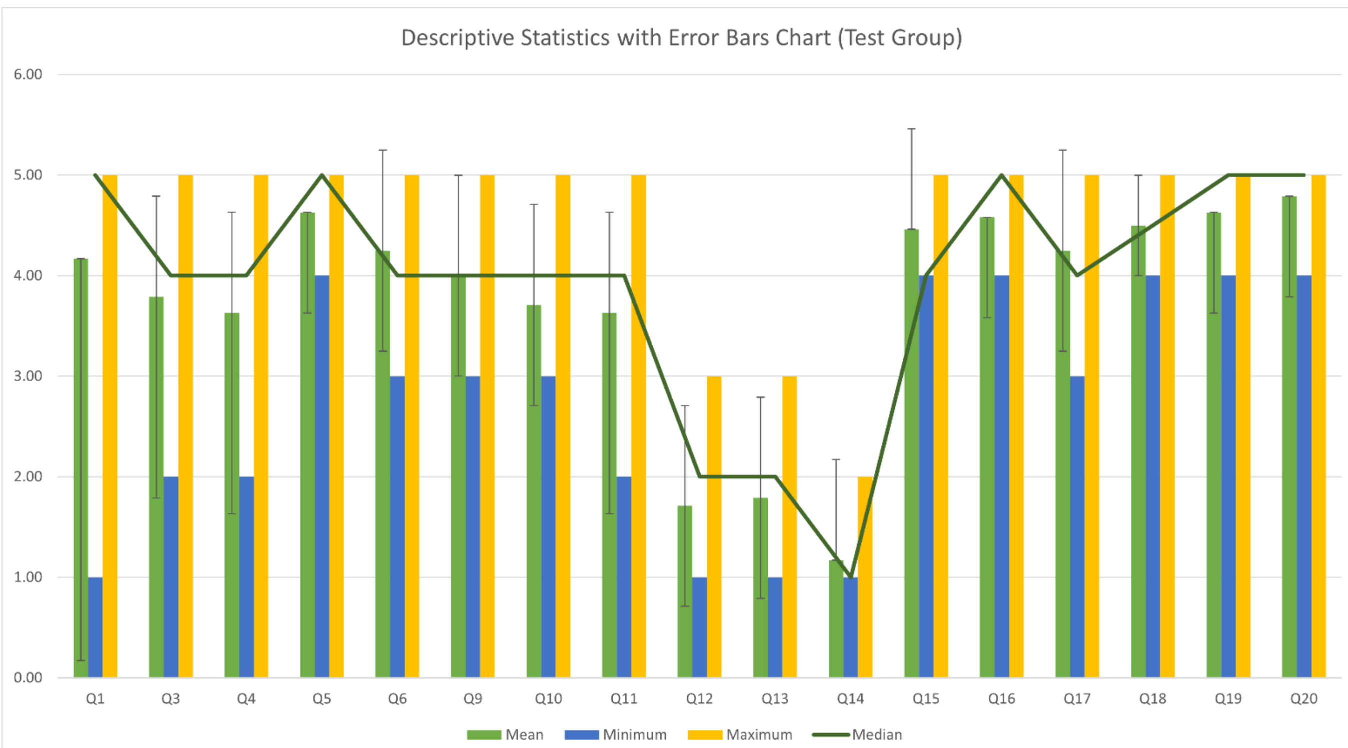

Figure 4.12 Descriptive Statistics with Error Bars Chart (Test Group)

Fig 4.12 showcases the same information in Fig 4.10 and 4.11 using a combined chart utilizing clustered column bars indicating the mean, minimum and maximum values for each question. It also includes a line graph with the median values. The error bars indicate how far the responses can deviate from the central tendency. For example, Q1 had the most deviation in the test group, followed by Q2. The difference between maximum and minimum values is mostly moderate except for the first three questions. The median is consistently high except for the three questions with a positive negative response (Q12, Q13, Q14).

Descriptive Analysis for user experience and immersion group (Control Group)

		Q1	Q3	Q4	Q5	Q6	Q9	Q10
N	Valid	24	24	24	24	24	24	24
	Missing	0	0	0	0	0	0	0
Mean		3.88	3.25	3.13	2.54	4.25	2.75	2.42
Median		4.50	3.00	3.00	3.00	4.00	3.00	2.00
Mode		5	3	3	3	4	3	2
Std. Deviation		1.296	.737	.741	.658	.608	.676	.654
Variance		1.679	.543	.549	.433	.370	.457	.428
Range		4	3	3	3	2	2	3
Minimum		1	2	2	1	3	2	1
Maximum		5	5	5	4	5	4	4

Figure 4.13 The descriptive analysis of the control group (Part 1)

Descriptive Analysis for the user experience and immersion group (Control Group)

		Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
N	Valid	24	24	24	24	24	24	24	24	24	24
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		2.38	2.13	1.54	1.08	3.92	4.21	3.54	4.42	4.29	4.88
Median		2.00	2.00	1.50	1.00	4.00	4.00	3.50	4.00	4.00	5.00
Mode		2	2	1	1	4	4	3	4	4	5
Std. Deviation		.711	.680	.588	.282	.830	.509	.588	.504	.464	.338
Variance		.505	.462	.346	.080	.688	.259	.346	.254	.216	.114
Range		3	2	2	1	3	2	2	1	1	1
Minimum		1	1	1	1	2	3	3	4	4	4
Maximum		4	3	3	2	5	5	5	5	5	5

Figure 4.14 The descriptive analysis of the control group (Part 2)

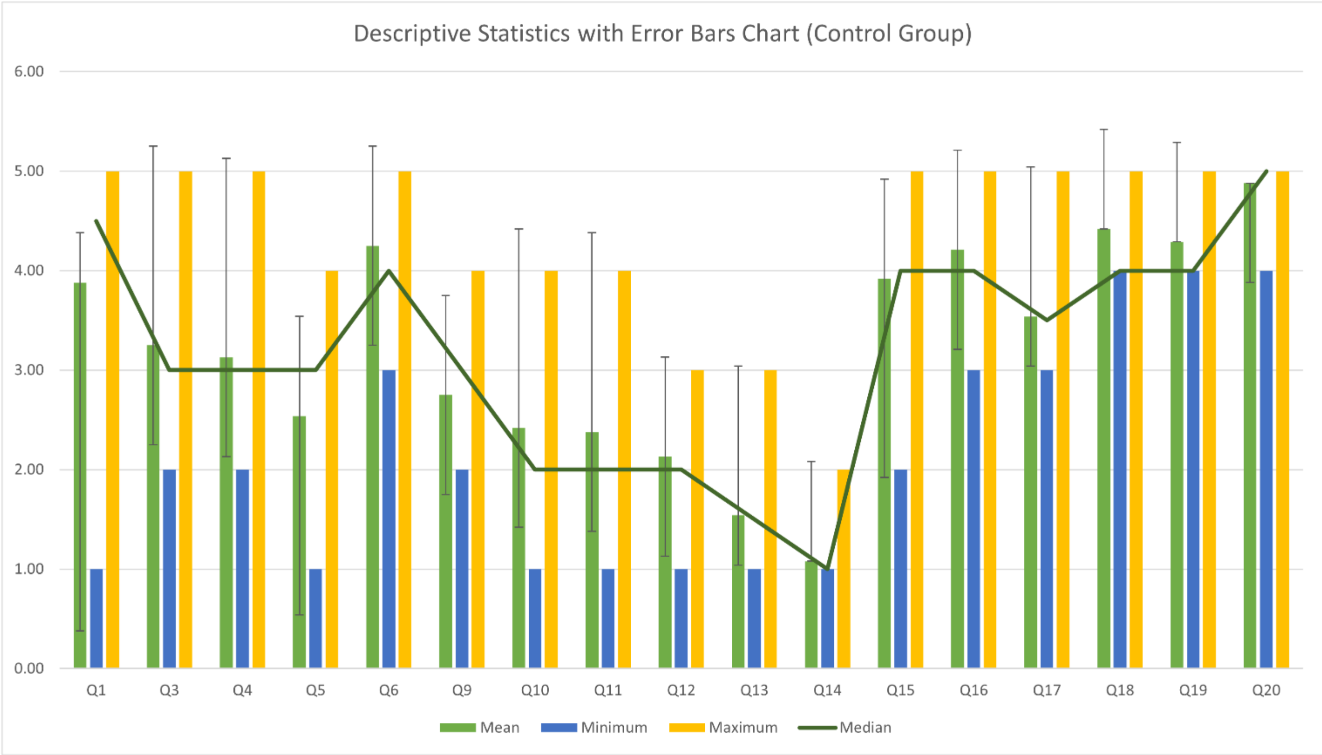

Figure 4.15 Descriptive Statistics with Error Bars Chart (Control Group)

Fig 4.15 summarizes Figures 4.13 and 4.14 and it can be noticed that the difference between maximum and minimum values are on average bigger than compared to the test group. The median is also less consistent than the test group. Furthermore, visually the error bars are on average longer than the test group indicating greater deviation in the responses of each question.

Descriptive Analysis for the user experience and immersion group

		Q1	Q3	Q4	Q5	Q6	Q9	Q10
N	Valid	48	48	48	48	48	48	48
	Missing	0	0	0	0	0	0	0
Mean		4.02	3.52	3.38	3.58	4.25	3.38	3.06
Median		5.00	4.00	3.00	4.00	4.00	3.00	3.00
Mode		5	4	3	5	4	3[a]	3
Std. Deviation		1.194	.799	.733	1.200	.636	.914	.954
Variance		1.425	.638	.537	1.440	.404	.835	.911
Range		4	3	3	4	2	3	4
Minimum		1	2	2	1	3	2	1
Maximum		5	5	5	5	5	5	5

a. Multiple modes exist. The smallest value is shown

Figure 4.16 The descriptive analysis of the user experience and immersion group (Test & Control, Part 1)

Descriptive Analysis for the user experience and immersion group

		Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
N	Valid	48	48	48	48	48	48	48	48	48	48
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		3.00	1.92	1.67	1.13	4.19	4.40	3.90	4.46	4.46	4.83
Median		3.00	2.00	2.00	1.00	4.00	4.00	4.00	4.00	4.00	5.00
Mode		2[a]	2	2	1	4	4	4	4	4	5
Std. Deviation		.923	.739	.663	.334	.734	.536	.692	.504	.504	.377
Variance		.851	.546	.440	.112	.539	.287	.478	.254	.254	.142
Range		4	2	2	1	3	2	2	1	1	1
Minimum		1	1	1	1	2	3	3	4	4	4
Maximum		5	3	3	2	5	5	5	5	5	5

a. Multiple modes exist. The smallest value is shown

Figure 4.17 The descriptive analysis of the user experience and immersion group (Test & Control, Part 2)

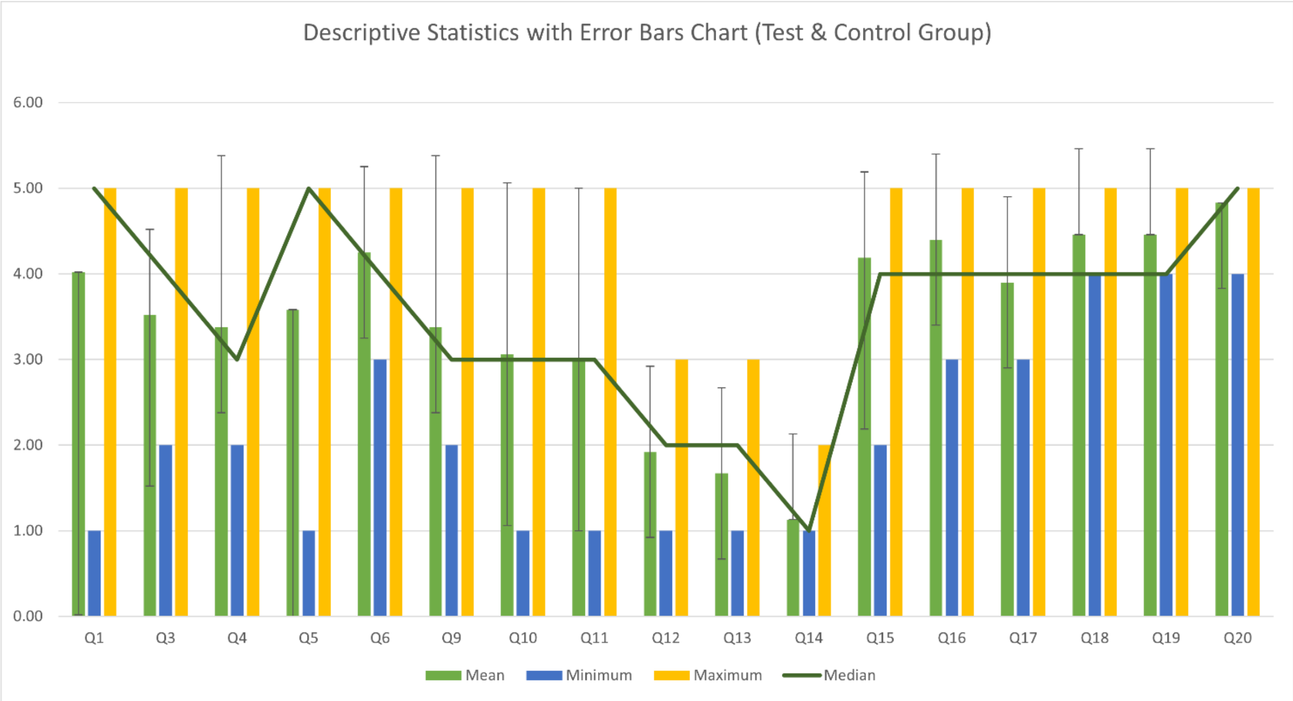

Figure 4.18 Descriptive Statistics with Error Bars Chart (Test & Control Group)

Fig. 4.18 showcases the visual results of the descriptive analysis tables similar to the charts for each of the groups individually. Visually it can be seen that when results are combined the error bars for almost half the question have great deviation while the other half have less deviation. The difference between minimum and maximum for the most part seems to be big. The median line starts off inconsistent but becomes more consistent towards the last five questions.

The second main objective of the final trial was to measure the learning impact from the tool compared to a traditional passive method like reading off information from a slide. Similarly, this group was further divided into two groups, one trying out the tool and one acting as the control group and using slides. An example game was developed by the researcher using the tool to teach specific basic information about the Kristang culture. The participants would have to play the game on the tool and learn through that process. The same information taught by the game was included in a passive way on slides, that the participants in the control group had to read instead.

The participants in this group had to fill up a knowledge survey asking basic questions about the Kristang culture three times. Once before they play the game or read the slides, once right after, and once after five days have passed. To measure the learning impact, three main metrics were used, namely the learning gain, memory retention, and knowledge retention. Learning gain is the immediate gain of knowledge after either playing the game or reading the slides. This is best calculated by checking if a participant answered a question wrong before the trial, and then answered correctly right after. It does not count those who answered a question correct before and correct after.

Memory retention measures if a participant remembered their post-trial answer after five days, and this is to simply measure if the chosen method of teaching helps in remembering. Knowledge retention measures if a participant remembered their correct post-trial answer after five days, thus retaining knowledge, and that makes this the most effective and useful metric. These metrics were adapted into this research based on the established work by (Sanzana, et al., 2021).

For every question, the learning gain was calculated by dividing the difference between correct answers after and correct answer before by the number of students in the group being tested, and the final learning gain value was calculated by summing up the value for each question and dividing it by the total number of questions. For example, this was repeated for males and females separately in each group, and also calculated for each group separately (test group versus control group).

Memory retention calculates the number of students who answered the same answer in their post-trial survey and also their five days post-trial survey. It is calculated as a percentage in a similar way to learning gain. Knowledge retention calculates only those students that answered the correct same answer in their post-trial survey and their five days post-trial survey. The main difference here is that memory retention identifies if a participant remembers their post-trial answer after five days and knowledge retention identifies if a participant remembers their post-trial answer but that answer has to be the correct one.

For Q1, the males in the test group had a learning gain value of **62.50%**, a memory retention value of **100%**, and knowledge retention value of **81.25%**. The females had a learning gain value of **75.00%**, a memory retention value of **100%**, and a knowledge retention value of **100%**. This resulted in a combined learning gain value of **66.67%**, memory retention value of **100%**, and knowledge retention value of **87.50%**.

The males in the control group had a learning gain value of **62.50%**, memory retention value of **81.25%**, and knowledge retention value of **62.50%**. The females had a learning gain value of **62.50%**, a memory retention value of **100%**, and knowledge retention value of **100%**. This resulted in a combined learning gain value of **62.50%**, a memory retention value of **87.50%**, and a knowledge retention value of **75.00%**.

For Q2, the males in the test group had a learning gain value of **12.50%**, a memory retention value of **100%**, and knowledge retention value of **100%**. The females had a learning gain value of **25.00%**, a memory retention value of **100%**, and a knowledge retention value of **100%**. This resulted in a combined learning gain value of **16.67%**, memory retention value of **100%**, and knowledge retention value of **100%**.

The males in the control group had a learning gain value of **12.50%**, memory retention value of **100%**, and knowledge retention value of **93.75%**. The females had a learning gain value of **12.50%**, a memory retention value of **100%**, and knowledge retention value of **100%**. This resulted in a combined learning gain value of **12.50%**, a memory retention value of **100%**, and a knowledge retention value of **95.83%**.

For Q3, the males in the test group had a learning gain value of **75.00%**, a memory retention value of **100%**, and knowledge retention value of **100%**. The females had a learning gain value of **62.50%**, a memory retention value of **100%**, and a knowledge retention value of **100%**. This resulted in a combined learning gain value of **70.83%**, memory retention value of **100%**, and knowledge retention value of **100%**.

The males in the control group had a learning gain value of **75.00%**, memory retention value of **100%**, and knowledge retention value of **100%**. The females had a learning gain value of **50.00%**, a memory retention value of **100%**, and knowledge retention value of **100%**. This resulted in a combined learning gain value of **66.67%**, a memory retention value of **100%**, and a knowledge retention value of **100%**.

For Q4, the males in the test group had a learning gain value of **62.50%**, a memory retention value of **87.50%**, and knowledge retention value of **81.25%**. The females had a learning gain value of **75.00%**, a memory retention value of **100%**, and a knowledge retention value of **100%**. This resulted in a combined learning gain value of **66.67%**, memory retention value of **91.67%**, and knowledge retention value of **87.50%**.

The males in the control group had a learning gain value of **62.50%**, memory retention value of **93.75%**, and knowledge retention value of **75.00%**. The females had a learning gain value of **62.50%**, a memory retention value of **87.50%**, and knowledge retention value of **87.50%**. This resulted in a combined learning gain value of **62.50%**, a memory retention value of **91.67%**, and a knowledge retention value of **79.17%**.

For Q5, the males in the test group had a learning gain value of **75.00%**, a memory retention value of **87.50%**, and knowledge retention value of **81.25%**. The females had a learning gain value of **87.50%**, a memory retention value of **87.50%**, and a knowledge retention value of **87.50%**. This resulted in a combined learning gain value of **79.17%**, memory retention value of **87.50%**, and knowledge retention value of **83.33%**.

The males in the control group had a learning gain value of **62.50%**, memory retention value of **75.00%**, and knowledge retention value of **62.50%**. The females had a learning gain value of **75.00%**, a memory retention value of **75.00%**, and knowledge retention value of **75.00%**. This resulted in a combined learning gain value of **66.67%**, a memory retention value of **75.00%**, and a knowledge retention value of **66.67%**.

For Q6, the males in the test group had a learning gain value of **31.25%**, a memory retention value of **100%**, and knowledge retention value of **100%**. The females had a learning gain value of **50.00%**, a memory retention value of **100%**, and a knowledge retention value of **100%**. This resulted in a combined learning gain value of **37.50%**, memory retention value of **100%**, and knowledge retention value of **100%**.

The males in the control group had a learning gain value of **43.75%**, memory retention value of **100%**, and knowledge retention value of **100%**. The females had a learning gain value of **50.00%**, a memory retention value of **100%**, and knowledge retention value of **100%**. This resulted in a combined learning gain value of **45.83%**, a memory retention value of **100%**, and a knowledge retention value of **100%**.

For Q7, the males in the test group had a learning gain value of **56.25%**, a memory retention value of **81.25%**, and knowledge retention value of **62.50%**. The females had a learning gain value of **62.50%**, a memory retention value of **87.50%**, and a knowledge retention value of **75.00%**. This resulted in a combined learning gain value of **58.33%**, memory retention value of **83.33%**, and knowledge retention value of **66.67%**.

The males in the control group had a learning gain value of **50.00%**, memory retention value of **81.25%**, and knowledge retention value of **50.00%**. The females had a learning gain value of **62.50%**, a memory retention value of **87.50%**, and knowledge retention value of **62.50%**. This resulted in a combined learning gain value of **54.17%**, a memory retention value of **83.33%**, and a knowledge retention value of **54.17%**.

For Q8, the males in the test group had a learning gain value of **50.00%**, a memory retention value of **50.00%**, and knowledge retention value of **43.75%**. The females had a learning gain value of **37.50%**, a memory retention value of **75.00%**, and a knowledge retention value of **50.00%**. This resulted in a combined learning gain value of **45.83%**, memory retention value of **58.33%**, and knowledge retention value of **45.83%**.

The males in the control group had a learning gain value of **18.75%**, memory retention value of **50.00%**, and knowledge retention value of **25.00%**. The females had a learning gain value of **37.50%**, a memory retention value of **62.50%**, and knowledge retention value of **37.50%**. This resulted in a combined learning gain value of **25.00%**, a memory retention value of **54.17%**, and a knowledge retention value of **29.17%**.

Grouping all these results together to form a summarized results shows that the total learning gain value of the males in the test group was **53.13%**, and memory retention was **88.28%**, and knowledge retention was **81.25%**. As for the females their learning gain value was **59.38%**, memory retention was **93.75%**, and finally their knowledge retention was **89.06%**. The overall learning gain value of the test group was **55.21%**, memory retention was **90.10%**, and knowledge retention was **83.85%**.

Comparing with the control group, their males had a learning gain value of **48.44%**, memory retention value of **85.16%**, and knowledge retention value of **71.09%**. Their females had a learning gain value of **51.56%**, memory retention value of **89.06%**, and knowledge retention value of **82.81%**. Finally, their combined totals are learning gain value of **49.48%**, memory retention value of **86.46%**, and knowledge retention of **75.00%**.

Overall, the learning impact of the tool was better across most questions and most importantly it was better across the totals. With the tool there was better immediate learning gain, better memory retention and most importantly better knowledge retention. Fig 4.19 shows a bar plot with the comparisons of the performance of males and females for each group. The orange bar plot represents the males in the test group, the light blue bar represents the males in the control group, the grey bar represents the females in the test group and finally the blue bar represents the females in the control group.

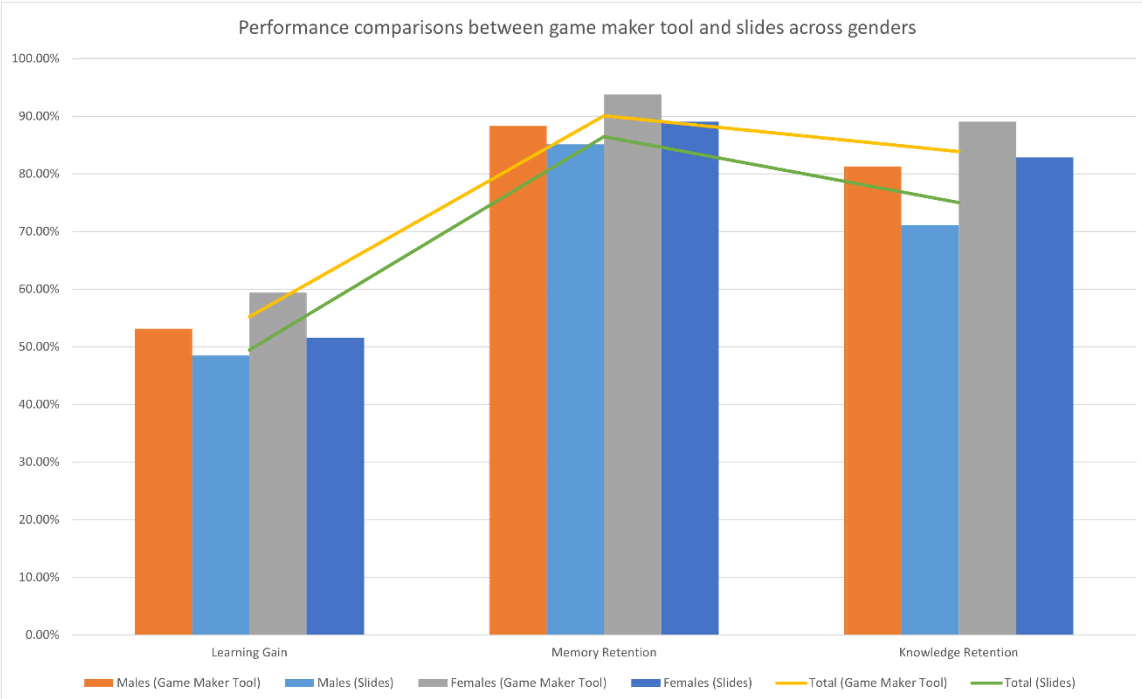

Figure 4.19 A bar plot comparing the performance between the test group and control group when using the game maker tool to learn about the Kristang culture

4.4.5 Inferential Analysis

To better understand the data further inferential analysis on the user experience and immersion group was conducted. Using the Pearson Correlation method it was found that the correlation coefficient **r** between Q3 and Q5 was **0.387** while the Sig. (2-tailed) p-value is **0.007** which means those two questions are significantly correlated indicating that the easier the participants find the tool they are using, the easier it was for them to incorporate the Kristang culture into their stories. Similarly, Q4 and Q5 had a correlation coefficient of **0.399** with a Sig. (2-tailed) p-value of **0.005** indicating that the easier the participants found it to translate their ideas into a story using the tool used, the easier it was to incorporate the Kristang cultures into the stories. Fig 4.20 shows the correlation analysis.

Correlations

		Q3	Q4	Q5
Q3	Pearson Correlation	1	.059	.387**
	Sig. (2-tailed)		.690	.007
	N	48	48	48
Q4	Pearson Correlation	.059	1	.399**
	Sig. (2-tailed)	.690		.005
	N	48	48	48
Q5	Pearson Correlation	.387**	.399**	1
	Sig. (2-tailed)	.007	.005	
	N	48	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.20 Correlation analysis between Q3,4, and 5 for the user experience and immersion group

Furthermore, more correlation analysis reveals that the immersion questions (Q9-Q20) are mostly correlated with each other. For example, Q9 is statistically correlated with Q10, Q11, Q15, and Q17, but negatively correlated with Q12 and not significantly correlated with Q13 and Q14. Fig 4.21 shows more correlation values for Q9-Q17. From the table it can be seen that the experience of the users and especially their immersion reflects on how they also find the appeal of the tool they are using, with more immersion leading to more appeal.

Correlations

		Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17
Q9	Pearson Correlation	1	.412**	.530**	-.016	.176	.052	.464**	.255	.332*
	Sig. (2-tailed)		.004	<.001	.915	.233	.724	<.001	.080	.021
	N	48	48	48	48	48	48	48	48	48
Q10	Pearson Correlation	.412**	1	.677**	-.264	.101	.042	.317*	.242	.332*
	Sig. (2-tailed)	.004		<.001	.070	.495	.778	.028	.098	.021
	N	48	48	48	48	48	48	48	48	48
Q11	Pearson Correlation	.530**	.677**	1	-.125	.139	.138	.283	.345*	.367*
	Sig. (2-tailed)	<.001	<.001		.398	.346	.350	.051	.016	.010
	N	48	48	48	48	48	48	48	48	48
Q12	Pearson Correlation	-.016	-.264	-.125	1	.376**	-.043	.069	.031	-.184
	Sig. (2-tailed)	.915	.070	.398		.008	.771	.643	.832	.211
	N	48	48	48	48	48	48	48	48	48
Q13	Pearson Correlation	.176	.101	.139	.376**	1	.288*	.087	-.220	.155
	Sig. (2-tailed)	.233	.495	.346	.008		.047	.555	.134	.294
	N	48	48	48	48	48	48	48	48	48
Q14	Pearson Correlation	.052	.042	.138	-.043	.288*	1	.249	-.045	.150
	Sig. (2-tailed)	.724	.778	.350	.771	.047		.087	.764	.310
	N	48	48	48	48	48	48	48	48	48
Q15	Pearson Correlation	.464**	.317*	.283	.069	.087	.249	1	.349*	.291*
	Sig. (2-tailed)	<.001	.028	.051	.643	.555	.087		.015	.045
	N	48	48	48	48	48	48	48	48	48
Q16	Pearson Correlation	.255	.242	.345*	.031	-.220	-.045	.349*	1	.229
	Sig. (2-tailed)	.080	.098	.016	.832	.134	.764	.015		.118
	N	48	48	48	48	48	48	48	48	48
Q17	Pearson Correlation	.332*	.332*	.367*	-.184	.155	.150	.291*	.229	1
	Sig. (2-tailed)	.021	.021	.010	.211	.294	.310	.045	.118	
	N	48	48	48	48	48	48	48	48	48

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 4.21 Correlations between Q9-Q17 for the user experience and immersion group

Questions 15 and 16 were statistically significantly correlated with Q19 which can indicate that the way the users perceived the interface and appeal of the tool could influence how rewarding the experience was. Further correlation values between Q15-Q20 are shown in Figure 4.22.

Correlations

		Q15	Q16	Q17	Q18	Q19	Q20
Q15	Pearson Correlation	1	.349*	.291*	-.065	.166	-.115
	Sig. (2-tailed)		.015	.045	.662	.261	.434
	N	48	48	48	48	48	48
Q16	Pearson Correlation	.349*	1	.229	-.056	.339*	.123
	Sig. (2-tailed)	.015		.118	.706	.019	.405
	N	48	48	48	48	48	48
Q17	Pearson Correlation	.291*	.229	1	.079	.384**	.014
	Sig. (2-tailed)	.045	.118		.594	.007	.927
	N	48	48	48	48	48	48
Q18	Pearson Correlation	-.065	-.056	.079	1	.329*	-.486**
	Sig. (2-tailed)	.662	.706	.594		.023	<.001
	N	48	48	48	48	48	48
Q19	Pearson Correlation	.166	.339*	.384**	.329*	1	-.150
	Sig. (2-tailed)	.261	.019	.007	.023		.310
	N	48	48	48	48	48	48
Q20	Pearson Correlation	-.115	.123	.014	-.486**	-.150	1
	Sig. (2-tailed)	.434	.405	.927	<.001	.310	
	N	48	48	48	48	48	48

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.22 Correlations between Q15-Q20 for the user experience and immersion group

Q1 was included to understand if participants with more familiarity with video games will find the trial easier. Two separate correlation results were obtained between Q1 and Questions 12, 13 and 14 for each of the groups. There was a strong negative correlation between Q1 and Questions 12 and 13 which does indicate that the more familiar the participants were with video games the less frustrating and confusing the toolkit was for them. This hypothesis is proved further when there was no significant correlation between Q1 and the same question with the control group. Figures 4.23 and 4.24 show the two different results.

Correlations

		Q1	Q12	Q13	Q14
Q1	Pearson Correlation	1	-.682**	-.728**	.035
	Sig. (2-tailed)		<.001	<.001	.871
	N	24	24	24	24
Q12	Pearson Correlation	-.682**	1	.686**	-.279
	Sig. (2-tailed)	<.001		<.001	.187
	N	24	24	24	24
Q13	Pearson Correlation	-.728**	.686**	1	.132
	Sig. (2-tailed)	<.001	<.001		.539
	N	24	24	24	24
Q14	Pearson Correlation	.035	-.279	.132	1
	Sig. (2-tailed)	.871	.187	.539	
	N	24	24	24	24

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4.23 Correlations between Q1, Q12, Q13, and Q14 for the test group

Correlations

		Q1	Q12	Q13	Q14
Q1	Pearson Correlation	1	-.327	-.021	.267
	Sig. (2-tailed)		.119	.921	.207
	N	24	24	24	24
Q12	Pearson Correlation	-.327	1	.150	.397
	Sig. (2-tailed)	.119		.486	.055
	N	24	24	24	24
Q13	Pearson Correlation	-.021	.150	1	.502*
	Sig. (2-tailed)	.921	.486		.012
	N	24	24	24	24
Q14	Pearson Correlation	.267	.397	.502*	1
	Sig. (2-tailed)	.207	.055	.012	
	N	24	24	24	24

*. Correlation is significant at the 0.05 level (2-tailed).

Figure 4.24 Correlations between Q1, Q12, Q13, and Q14 for the control group

To determine statistically which questions had significant differences between the two groups, a multivariate analysis of variance was conducted using the fixed factor of the tool used. A significance value of 0.05 was initially set and further corrected due to multiple tests using the Bonferroni correction method to be 0.003 indicating that any p-value under that value would be considered a significant difference. Fig 4.25 shows the table with the analysis.

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Q3	3.521[a]	1	3.521	6.121	.017
	Q4	3.000[b]	1	3.000	6.202	.016
	Q5	52.083[c]	1	52.083	153.743	<.001
	Q6	.000[d]	1	.000	.000	1.000
	Q9	18.750[e]	1	18.750	42.073	<.001
	Q10	20.021[f]	1	20.021	40.408	<.001
	Q11	18.750[g]	1	18.750	40.588	<.001
	Q12	2.083[h]	1	2.083	4.064	.050
	Q13	.750[i]	1	.750	1.732	.195
	Q14	.083[j]	1	.083	.742	.394
	Q15	3.521[k]	1	3.521	7.432	.009
	Q16	1.688[l]	1	1.688	6.583	.014
	Q17	6.021[m]	1	6.021	16.828	<.001
	Q18	.083[n]	1	.083	.324	.572
	Q19	1.333[o]	1	1.333	5.795	.020
	Q20	.083[p]	1	.083	.582	.449

Figure 4.25 Multivariance analysis of variance for the user experience and immersion group

As seen from the table not all questions had significant differences between the two groups. The questions that had the most significant differences were Q5, Q9, Q10, Q11, and Q17. Q15 had a p-value of 0.09 but it was still above threshold and therefore not having as many significant differences as the rest. These questions mostly indicated significant differences when it comes to representing the Kristang culture, the immersion with the tool used and how it appealed to the senses. The positive feedback on these questions as discussed earlier shows an advantage for the tool over the storyboarding as the tool was more immersive, more target specific because of Kristang specific assets and appealed more to the senses, which could be a result of better immersion. The storyboarding tool is still a good tool to use as seen by how most of the other questions did not have as much of a significant difference, however, the tool seems to have further improved on that experience.

A Mann-Whitney U test was carried out to find out if there was a significant statistical difference between the test and control group responses, which was carried out on questions from Q3 to Q20, excluding Q7 and Q8. For Q3 the Mann-Whitney score was 69.5 and the p-value was 0.01, indicating no significant difference considering the newly corrected significance value of 0.003.

For Q4 the Mann-Whitney score was 175.5 and the p-value was 0.011 showing no significant difference between the two groups. For Q5 the Mann-Whitney score was 4.5 and the p-value was less than 0.001, showing a very significant difference between the two groups. For Q6 the Mann-Whitney score was 285 with a p-value of 0.945, showing that there was no statistically significant difference between the two groups.

For Q9 the Mann-Whitney score was 66 with a p-value score of less than 0.001 which shows significant statistical difference between the two groups. Similarly, Q10 had a Mann-Whitney score of 65 and a p-value score less than 0.001 indicating once more a significant statistical difference. Fig. 4.26 shows the table with the Mann-Whitney U test results for Questions from 3 to 10 excluding 7 and 8 between the control and test group.

Mann-Whitney U Test for the user experience and immersion group[a]

	Q3	Q4	Q5	Q6	Q9	Q10
Mann-Whitney U	172.000	175.500	4.500	285.000	66.000	65.000
Wilcoxon W	472.000	475.500	304.500	585.000	366.000	365.000
Z	-2.582	-2.530	-6.042	-.069	-4.815	-4.851
Asymp. Sig. (2-tailed)	.010	.011	<.001	.945	<.001	<.001
Exact Sig. (2-tailed)	.010	.012	<.001	1.000	<.001	<.001
Exact Sig. (1-tailed)	.005	.006	<.001	.500	<.001	<.001
Point Probability	.001	.001	.000	.073	.000	.000

a. Grouping Variable: Method_Numeric

Figure 4.26 The Mann-Whitney U Test for Q3-Q10 (exc. Q7 and Q8) for the user experience and immersion group

For Q11 the Mann-Whitney score was 69.5 and the p-value score was less than 0.001 showing a significant statistical difference between the two groups. For Q12 the Mann-Whitney score was 198.5 and the p-value was 0.047 which shows no significant difference between the groups. Q13 had the Mann-Whitney score of 235 but the p-value was 0.232 showing no significant difference and similarly Q14 had a Mann-Whitney score of 264 and a p-value score of 0.388 indicating no significant difference.

Q15 had a Mann-Whitney score of 182.5 and a p-value score of 0.017 and Q16 had a Mann-Whitney score of 187 and a p-value score 0.016 showing no significant difference while Q17 had a Mann-Whitney score of 131 and a p-value score less than 0.001 which shows that it has statistically significant differences between the two groups.

Q18 had a Mann-Whitney score of 264 and p-value score of 0.566 showing no significant differences, Q19 had a Mann-Whitney score of 192 and p-value score of 0.022 indicating no significant differences and finally Q20 had a Mann-Whitney score of 264 and p-value score of 0.433 indicating no significant differences between the two groups. Fig 4.27 shows the table with the Mann-Whitney results for Questions 11 to 20.

Overall, some of the questions had significantly statistical differences between the two groups which provides useful information in how using the tool was different than using the storyboarding tool when it comes to designing and creating a serious cultural game about the Kristang culture.

Mann-Whitney U Test for the user experience and immersion group[a]

	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
Mann-Whitney U	69.500	198.500	235.500	264.000	182.500	187.000	131.000	264.000	192.000	264.000
Wilcoxon W	369.500	498.500	535.500	564.000	482.500	487.000	431.000	564.000	492.000	564.000
Z	-4.745	-1.988	-1.196	-.864	-2.389	-2.405	-3.558	-.573	-2.293	-.766
Asymp. Sig. (2-tailed)	<.001	.047	.232	.388	.017	.016	<.001	.566	.022	.443
Exact Sig. (2-tailed)	<.001	.046	.268	.666	.018	.028	<.001	.772	.041	.701
Exact Sig. (1-tailed)	<.001	.023	.134	.333	.009	.014	<.001	.386	.021	.350
Point Probability	.000	.007	.032	.239	.001	.010	.000	.194	.017	.228

a. Grouping Variable: Method_Numeric

Figure 4.27 The Mann-Whitney U Test results for Questions 11 to 20 for the user experience and immersion group

To measure the learning impact of using the tool compared to the control group it was important to calculate the three metrics mentioned earlier, however it is important to conduct further inferential analysis to determine the impact of the differences between the data. A suitable method to use when comparing the nominal data from two groups is the

Chi Square analysis to determine if there are significant differences between the data of the two groups, in this case the test group and the control group. For each of the eight questions in the survey used the learning gain, memory retention and knowledge retention were calculated and for each participant these were simply depicted as a simple "Yes" or "No" depending on if for any particular participant they had gained any learning, retained memory, or retained knowledge. This was only calculated after analyzing the response of each participant across the three surveys they filled out.

There are two values in a Chi-Square test that help in determining how statistically different two groups are, one being the Chi-Square value which is the degree to which the observed frequencies differ from the expected frequencies meaning that a higher value would mean greater discrepancy. The second is the p-value which indicates the probability of observing a Chi-Square value as extreme or more extreme than the one obtained, and typically a value of p under 0.1 or 0.05 indicates statistical significance.

For each question there is a Chi-Square value and p-value based on each of the three metrics which are learning gain, memory retention, and knowledge retention. For Q1, the learning gain Chi-Square value was 0.091 with an accompanying p-value of 0.763 indicating no significant statistical differences between the two groups. For the memory retention there was higher discrepancy with a Chi-Square value of 3.2 and a p-value of 0.074 indicating moderate statistical significance. Finally, the knowledge retention had a Chi-Square value of 1.231 and a p-value of 0.267 indicating no statistical significance.

For Q2 the learning gain Chi-Square value was 0.167 with a corresponding p-value of 0.683 indicating no significant statistical differences. The memory retention Chi-Square value could not be produced because both groups had only one constant and the knowledge retention had a Chi-Square value of 1.021 and a corresponding p-value of 0.312 indicating no significant statistical differences.

For Q3 the learning gain Chi-Square value was 0.097 and the p-value was 0.755, the memory retention and knowledge Chi-Square value could not be produced because both groups had one constant.

Q4 had a Chi-Square value of 0.091 and a p-value of 0.763 for the learning gain, memory retention had a Chi-Square value of 0 with a corresponding p-value of 1 since the two groups had the same exact result and finally the knowledge retention had a Chi-Square value of 0.6 and a p-value of 0.439.

Q5 had a Chi-Square value of 0.949 and a corresponding p-value of 0.330 indicating no significant differences, memory retention had a Chi-Square value of 1.231 showing slight discrepancy and a p-value of 0.267. Knowledge retention had a Chi-Square value of 1.778 and a p-value of 0.182 showing the most significant difference in the three metrics for this question, but not quite significantly different overall.

Q6 had the Chi-Square value of 0.343 and a p-value of 0.558 for the learning while the memory retention and knowledge retention could be calculated as they had only one constant.

Q7 had the Chi-Square value of 0.085 and a p-value of 0.771 indicating no significant difference, memory retention had a Chi-Square value of 0 and a p-value of 1 since both groups had exact result and finally knowledge retention had a Chi-Square value of 0.784 and a p-value of 0.556.

Finally, Q8 had a Chi-Square value of 0.343 with a p-value of 0.558, memory retention had a Chi-Square value of 0.085 and a p-value of 0.771 and knowledge retention had a Chi-Square value of 1.422 and a p-value of 0.233.

Overall, the Chi-Square test showed that despite the groups being different they did not have noticeably statistically different results, which could be a result to the Chi-Square test being less sensitive compared to the Mann-Whitney test. By comparing the average percentages of both groups, it could be noticed that the test group had slightly better results compared to the control group as discussed in the descriptive analysis of this trial, however, when analyzing based on a sample it is important to take into considerations tests like the Chi-Square.

The Chi-Square however does not measure very accurately when presented with a small sample size, and in this case the total sample size was only 48 participants which might be too small of a sample to draw accurate conclusions from. The trial also measured learning impact from only eight questions which were not very challenging and could have impacted how the tool's effectiveness in teaching culture. The Chi-Square expects a minimum count of 5 entries per label in a category, but there were multiple entries that had less than that which could have impacted the measurements as well. Overall, further analysis would be needed with a much bigger sample size and preferably longer and more complex knowledge survey to extract more accurate information from the Chi-Square test.

4.5 Summary

This section included the formulative evaluation from the interviews conducted with the experts, teachers, and students. Their feedback has been demonstrated backed up by their quoted statements from the interview videos that were recorded while conducting the interviews. In short E1 pointed out that it is important to add historical facts to the assets used in the game, that the tool can also be used outside of a classroom and finally that the tool would be more beneficial if used after visiting the historical site to be demonstrated in the tool.

E2 stressed how language is the hardest to preserve and that it is a challenge to preserve it. Moreover, he pointed out that he believes games are the way to make culture reach the younger generations and finally he suggested adding actual historical facts to the games being designed with the tool.

The teachers were concerned about how the tool could be implemented properly in a classroom as T1 pointed out that the tool needs to have a proper guide for the students and teachers to make it easy to use in a classroom and also suggested that the users should be able to customize certain aspects of the tool like adding their own assets or modifying existing ones. T2 suggested using interculturalism while using the tool and also suggested that the tool can be used as young as 10 years. Finally, T3 suggested working with a teacher to add content to the tool, stressed how important it is to have a specific context to the tool to make sure the syllabus is being followed and finally pointed out that the assets in the game need to look realistic enough and be accurate compared to the actual models in real life.

Finally, the students shared their feedback, with S1 suggesting the addition of a quest list to help users develop their game and pointed out that he believes the tool would be better used individually rather than just in classrooms. S2 mentioned that it would be a great idea to allow the users to upload their own multimedia files into the game like audio or video and commented that the tool could be used for other topics besides culture. Finally, S3 was very clear about how personalization is important by suggesting features that allow the user to change the default setting of the scene and the ability to be able to add custom assets while also being able to modify existing ones.

The second evaluation trial was conducted, and school students got to try the tool and design their own cultural games about the Kristang culture. The participants provided positive feedback regarding certain parts of the tool but also negatives were pointed out, which is good for the progress of the research. User feedback is extremely crucial to develop a successful tool that caters to its target audience, which makes these smaller scale evaluation trials very important before complete development is over.

Based on the feedback from the participants, the GUI of the tool needed to be revised and polished, the controls made easier to understand while also adding guides inside the tool to assist users. Some aspects performed well, like creating quests where most participants had no issue in designing and adding quests. However, the lack of variation in assets and quest types limited the creativity of the participants. More quest variation was implemented shortly after this trial.

After the addition of the IoT features and ChatGPT as a virtual assistant, the final trial took place and tested the two main elements of the tool, namely designing a cultural story and playing a cultural story. The feedback was mostly positive and was better than the feedback from the groups that used a control method, namely designing a story on a storyboard and reading information from slides. The tool provided a positive and more immersive user experience and when it comes to learning it had better average outcomes in terms of immediate learning gain, memory retention, and knowledge retention, however, the results were not significantly statistically different from the control group. Further limitations and analysis are discussed in Chapter 5.

Chapter 5 Discussion

5.1 Introduction

This section will give additional insights into the results of the survey taken and the points taken out from the trial to improve the trial planning of the tool and the tool itself. It will also discuss the design guidelines drafted out of the interviews and the literature research. Moreover, it will discuss advantages and disadvantages gathered over the trial, and how the final tool tried to address them and what could be further enhanced. It also discusses the impacts of the final tool on the user experience and learning and how it can be used realistically.

5.2 Results Summary

This research set out a few aims and objectives and through various stages of the study those objectives have been met. The objectives and a summary of how each was achieved especially in relation to the results are mentioned below:

O1: To conduct a comprehensive literature review to analyse existing serious games developed for cultural heritage, identify available tools within this domain, and determine areas of deficiency or limitations – The literature review was analysed thoroughly, and the state of the research was identified. The gap in 3D game making tools and especially when it comes to creating cultural serious games was also realized.

O2: To design and develop a user-friendly 3D serious cultural game maker tool specifically tailored for the younger generation, ensuring it does not necessitate any programming or game development expertise – Based on the literature and the preliminary short trials and interviews the tool was designed, developed and improved. By considering the opinion of various experts and potential end users the tool was developed to cater to the needs of its audience.

O3: To engage in interviews with a diverse range of experts, educators, and education university students to gather feedback and insights throughout the development stages of the prototype, and synthesize this feedback with existing serious game design guidelines to formulate comprehensive design guidelines for the tool – Through the first prototype of the tool, the experts, educators and university students were able to provide valuable feedback that helped in guiding this research moving forward, by stressing on the important features, learning theories, and design choices that needed to be incorporated. This also helped in writing up initial design guidelines and improving the final version of it for future tools.

O4: To evaluate the user experience and immersion levels of the developed tool through user trials, and gather feedback from participants regarding various aspects of using the tool to create their own serious 3D cultural games – By conducting user trials and analysing the results through various descriptive and inferential analyses it could be concluded that the tool provided the users with an immersive experience and an overall satisfactory user experience.

O5: Assess the effectiveness of the developed tool in terms of learning gain, memory retention, and knowledge retention among a selected group of participants, and measure these outcomes after participants engage with a demo game created using the tool – By assessing the results from the user trial and conducting various descriptive and inferential analyses it could be deduced that while the results did show a positive impact on the learning outcomes, the difference in relation to the control method was not statistically significant.

5.3 Interviews and Literature Review

The formulative analysis of the interviews and the review of the literature regarding serious games framework have helped in designing general guidelines for serious cultural game maker tools. These guidelines are based on the qualitative analysis from the interviews, the literature review done on serious games, serious cultural games, and learning theories, and some of the feedback gained through the research. As discussed in Section 4.2.3 the interviews were analyzed using a qualitative analysis technique and the conclusions from that analysis helped in identifying key literature to include in the guidelines. For each point in the guidelines that has a corresponding point derived from the interviews, it will be stated within the guideline.

5.3.1 Design Guidelines

In this section a more comprehensive set of design guidelines is listed below, including the same points mentioned earlier in Section 3.6 that were used in the implementation of the tool used in this research. Additional points are added that could potentially result in a better tool design and could be used as a reference by future developers and researchers seeking to develop a similar tool in this domain.

1. **The tool needs to have easy to use, flexible building features to design levels –** Level design is very important for serious cultural games as how the scene looks like could already influence the players and teach them about the culture. According to the design framework developed by (Andreoli, et al., 2017), the design phase of designing a serious game scene is an iterative one. The user keeps visiting this phase after gaining more information about the culture and refining the story, so it is very important that the tools in the toolkit that allow for scene manipulation to be easy to use and flexible. Good implementation of this point would assist in integrating both the learner-centered and personalized learning approaches discussed in Sections 2.3.1 and 2.3.3.
2. **The tool should highlight the important cultural assets that the user can use –** This could be done by either providing critical information about those assets for the user designing the level, to imply the significance or by making sure that particular asset stands out when deployed in the scene using different methods like visual effects or special lighting to highlight the asset. This is inspired by the study conducted by (Raptis, et al., 2019) which evaluated how visual search tasks were affected by the way those visual aspects were implemented. By highlighting those visual aspects or assets the knowledge acquisition of the users could increase. This was also based on the results of the interview with experts E1 and E2 (See Section 4.2 and confirmed further by the teachers T2 and T3 (See

Section Teachers)). This promotes both the learner-centered approach and the personalized learning concept.

3. **The tool needs to provide robust logic tools to allow users to add cultural information easily –** When it comes to any cultural game, the learning component is one of the most important components in designing that game. Being able to add the information easily through the game logic should be in a very easy way so that the user can focus more on what content to add rather than suffer from trying to add it in the first place. The research done by (Ibrahim, et al., 2015) shows the cultural information in a virtual cultural heritage environment is one of the most important factors to facilitate cultural learning. A very important point is that it is crucial to assist the users in learning in their own way which works seamlessly with the learner-centered approach and allows for a variety of options to design games which in turn is a form of personalized learning.
4. **The assets, especially the cultural assets used in the tool need to be of high quality rendering –** According to the experiments done by (Ibrahim, et al., 2015) the users were more interested in the virtual environments that had better quality assets, which means that the assets used need to be of high quality in order to keep the players attracted and attentive. Also confirmed by the feedback from T3 (See Section 4.2.3). High quality assets will provide an immersive environment which will enhance the experiential learning approach that the developed games will provide for the learners.
5. **The tool should contain several audio elements, like background noises, music, etc. and should allow users to upload their own audio files as well –** This is a very important guideline as discussed by (Schofield, et al., 2019) on how the people interviewed in their research recognized sounds as one of the key elements that makes them think about their culture and how it adds to that sensory knowledge and provides a more immersive experience. Expert E1 suggested conversational audio as well as teacher T2 (See Section 4.2.3). Similar to the point above, a better immersive experience would lead to a more effective experiential learning approach.

6. **The tool should have a guiding mechanism to help the users create their conversational content –** If the user has not previously done research on which is the best way to deliver cultural information in a game, they would not know that information should be delivered in a way that provokes the user's interest. The user should get questioned by the game characters, solve simple puzzles, etc. to keep the user engaged and interested. This was the result of a research done by (Ibrahim & Ali, 2018). If implemented correctly this method would ensure that the learning content is delivered in a better way, vastly improving the implementation of the learner-centered approach by giving power to the learner and teaching them how to build effective educational games.
7. **The tool should provide the players with an easy way to navigate, and also allow the designers to add additional components to help the players navigate, like maps –** This was proven to be crucial by (Ibrahim & Ali, 2018) and (Ibrahim, et al., 2015) where the experiment showed that some users struggled to navigate the scene. By making the players playing the games developed by the toolkit have easy navigation, and by allowing designers to add elements like maps to ease the navigation process, the benefits of learning will be increased. This would apply the learner-centered approach more effectively and also the experiential learning approach.
8. **The tool should be personalized, allowing users to edit existing assets by changing their names, colours or even adding their own assets** – This was a suggested idea by multiple interviewees, precisely T1 and S3 (See Section 4.2.3). This aligns well with the personalized learning approach and encourages the learners to experiment and learn in their own way which also aligns with the learner-centered approach.

5.4 Advantages and Limitations

Based on the research done throughout this study, from literature review to interviews, to user trials, key insights about 3D cultural serious game making tools were discovered, the user experience of school students using such a tool were measured and the learning impact from using such tools was also explored. The research provided important key points and findings in this area of research and therefore, a list of advantages, limitations, and potential improvements are discussed to portray a clear picture on the outcome of the research.

5.4.1 Advantages

- The tool runs on computers, rather than on the Raspberry Pi which prevents issues due to low computational power, loss of data due to connection issues with the Pi and depending on a Raspberry Pi being there to use the tool.
- The tool provides an immersive experience that could spark interest in students and adults alike. The inclusion of IoT might increase that immersion and potentially increase the benefit of the tool. Backed by statements by E1, T2, T3, S1, S2 and S3 (See Section 4.2.3).
- The tool has a user-friendly interface that is easy to use by most participants. Based on comments by S1, S2 an S3 (See Section 4.2.3)
- The tool includes a virtual assistant that can guide the users in creating their Kristang themed stories for their games. While Scratch has plenty of tutorials to help, they are not specifically for help in designing cultural games which the tool has.
- The tool provided an immersive experience for the users while designing games which kept their attention for long and provided a good overall user experience.
- The tool provided good learning gains, memory, and knowledge retention when the users played the game designed by the tool, indicating that the immersion provided by the games designed can improve the learning experience.
- The research explored creating serious cultural games in an innovative way, and the results provide valuable feedback for the approach to help future research improvements.

5.4.2 Disadvantages

- The tool can only run on PCs and in offline mode, making it not accessible through a website like Scratch which definitely reduces its accessibility factor. The tool would have to be installed on a computer first before it can be used.

- The tool has a drawback on not having enough accurate cultural assets for users to use to design their games. Finding these assets is not easy and hiring professionals might be necessary to model those assets and that could cost a lot of money.
- The tool would require a thorough lesson plan or guide before it can be used in classrooms, which could be a very tedious task and could differ from one school syllabus to another. The concern has been stressed by T1 and T3 (See Section 4.2.3)
- The tool can be harder to use initially for users who are not familiar with video games, since the tool shares many similar control mechanics to common 3D computer video games.
- The research lacked enough participants to fully test out the hypothesis mentioned earlier and to determine the full impact of the tool developed in this work. Moreover, the experimental design especially in the questionnaire measuring the learning impact could have been designed different to include questions that are more challenging or require more memorization and visualization to properly test out learning using serious games.
- Numerically the tool developed provided a good user experience and a decent learning performance, however, deeper analysis proved that the performance when it comes to learning was not very different from the traditional teaching methods. This result could be impacted by the lack of participants and the questions asked to measure learning impact and therefore it is recommended that future researchers conduct trials with a larger number of participants, and questions that test out memory, concepts that are hard to visualize and increase the learning content in the games.

5.4.3 Improvements

- The tool needs to include a variety of accurate cultural assets to prevent the users from being confined in their designing process. They should be able to find enough assets to satisfy their creativity, or at least try to. This is an improvement that could not be fulfilled within this research due to monetary constraints.
- The tool could have a version that could run on web browsers. However, limitations might exist like not being able to run the Raspberry Pi. Scratch has a similar

drawback whereas Raspberry Pi extensions could only be used if Scratch is being run on the Pi itself, and not through the web browser.

- The tool could include features that allow users to upload their own audio files, images, videos or even assets. This would increase the aspect of customization and make the tool more personal as suggested by T1, T2 and S3 (See Section 4.2.3)
- The tool could allow a cross-input feature that would allow the users to control the tool using mouse and keyboard or using gamepad controllers which could make navigating the tool easier for some users who are more used to using controllers in 3D games. This could also improve accessibility by allowing disability-friendly controllers to be used.
- The tool could include more accessibility features to cater for disabled users, like including a colour blind option, text-to-speech option to read menu items, or other features that could assist impaired students while designing or playing games using the tool.
- The user trials need more participants to better understand the data and detect patterns. Performing user trials at different age groups and educational backgrounds could also prove to be useful.
- The questions testing out the knowledge learned from the using the tool or from passive means could be improved to include more challenging questions or questions that require more visualization to answer to test out the impact of getting immersed in the game compared to the non-visual passive reading method.

5.5 Final Tool Impact

This section discusses the impact, and lessons learned from the final trial with the final tool. It discusses how the user experience was and what can be improved, and it also discusses how the tool managed to impact learning of culture through its created serious games. Finally, it discusses how the tool can be further improved upon and what settings would work for it best.

5.5.1 Trial Design Rationale

The final trial was designed in a way that could potentially offer the best way to compare the toolkit with other methods of designing and learning. The chosen control method to compare with while designing a cultural game was storyboarding. Storyboarding is a 2D way of designing a story while the toolkit is a 3D tool and therefore making it a suitable control method since the tool offers an immersive 3D design experience and comparing it against a 2D method allows for more clear comparisons.

As for the learning aspect of the trial the traditional slides method was adopted as it is very common and the most basic form of learning available to almost all students. Having a teacher or lecturer teach the students as the control method was not appropriate as there are more volatile variables to that method, like students not paying attention to the teacher, the teacher's teaching quality, the learning environment, etc. However, by asking the students to read the slides and learn from it during the trial, these variables would cease to exist or minimize considerably, which makes it a viable control method.

5.5.2 Overall user experience

Based on the results discussed in Chapter 4 the overall user experience of using the tool to design a serious cultural Kristang game was positive. The participants did not suffer too much from the controls or the interface and were able to undertake the task at hand. Familiarity with video games seemed to help and that is not a negative as younger generations are increasingly becoming more tech savvy and video games are very popular amongst young people. Moving forward it is increasingly important to develop tools that resonate with the younger generations, and this tool was an attempt at that.

The designing aspect of the tool is very crucial as it is the part where the users would be learning by teaching which is, as discussed earlier, the best form of learning. A well-designed game will also therefore expose the users playing that game to the learning content in a good way, and those users would be learning by doing which is the second-best form of learning. By comparing the tool with the storyboarding tool and achieving a good result in the trial, the potential to use the tool to design games is realized. These results also validate the use of first-person view to design 3D games and the addition of IoT and

ChatGPT appear to enhance the experience and not take away from it, indicating that the design direction of the toolkit was on the right track. This is further validated when the two groups showed statistically significant responses indicating that the use of the tool was responsible for the difference.

5.5.3 Learning Impact

The learning impact from the toolkit was positive, as it performed better overall compared to the more traditional method of reading slides, at least when strictly comparing numerically. Deeper inferential analysis concluded that the differences were not significantly different, which could be due to multiple factors. The small sample size and the relative ease and number of questions asked could be a factor in the results. Previous research has already established the fact that serious games can be a better educational tool compared to traditional passive methods as they tend to be more immersive and keep the attention of the learner for longer. To fully understand the scope of the impact of the games created by this tool on the learning experience, it would be wise to research further with more students and present them with more questions that are also harder. However, there are promising signs in this work considering how the user experience while using the tool was satisfactory suggesting that there could be potential in this method if it was further refined.

5.5.4 Usage Scenario

Having a good tool is great, but without implementing and using it in the right scenario, the full potential of the tool might not be utilized. As previously mentioned, this tool is in no way a substitute for traditional lectures, or to replace teachers. This tool would not work well as a standalone teaching tool, but rather would act as a supplementary tool to enforce what was learnt and to add that fun element to learning.

Due to the social aspect of the tool that requires students to design games and play other student’s games, the students need to have some basic knowledge to act upon. This is best achieved through the classroom, after which it would make sense to allow the students to use the toolkit, similar to how the participants had access to reading material and ChatGPT to help them create their games.

Another point is the concept of the accuracy of the games designed by the users, and this was also stressed out by the experts and teachers during the interviews. If the users were to create games that teach wrong information, then there is more harm than benefit. Therefore, it is crucial that there is a teacher or supervisor overseeing the process and making sure that any game designed using the tool actually teaches relevant and accurate information before allowing the rest of the group to play it.

5.5.5 Technical Contribution

This research mostly focused on a development of an educational tool that aims to assist users in learning about cultures through designing games and playing them. First off, this tool's design was inspired by previous research and learning concepts discussed in Section 2.3 and the interviews conducted in the first trial as discussed earlier. The tool combined different concepts to stand out as its own unique idea and was evaluated accordingly. It successfully allowed young users with no prior coding knowledge to create fully functional 3D serious cultural games due to its core features. The first-person designing concept was inspired by the success of Minecraft (Microsoft, 2023) and the case study used was the Kristang culture. The tool accomplished its main goals by allowing students to express a culture through designing a game, and their experience and immersion proved to be better than the control method of storyboarding as proved by the statistical analysis conducted on the results between the test and control groups.

The learning impact from the tool was positive despite not being statistically different from the traditional passive method. However, there were multiple factors that could have impacted this result and therefore it does not remove the potential of the tool. Therefore, this tool is a great contribution to the maker movement and a good supporting tool for cultural education. Besides the technical contributions of the tool itself, IoT and AI were added to provide more accessibility features and immersion when using the tool, by incorporating RFID cards as an IoT feature to add an extra layer of physical immersion with the tool and adding ChatGPT to assist in designing stories for the games, the tool improves its usability and accessibility and provides a clear example on how these technologies can be added to improve a software beyond core features.

5.6 Future Work

This work started by researching existing methods and learning concepts and formed an initial idea that was later on improved by user feedback. This work differs from previous work reviewed like (Huang, et al., 2021), (Panzoli, 2012), (Tan & Ng, 2022) since they focused on creating a serious game for cultural education, with the focus being just on making a game. There is an obvious lack in game maker tools focusing on cultural heritage. Game making tools like Unreal Engine, Unity, and even platforms like Minecraft Education allow users to create serious games, but the first two are for developers only and Minecraft does not focus on cultural education. This work focuses on creating cultural serious games but also allows the users to play those games through the same tool.

However, this work could be further improved, and the main focus of any future work should be on improving the tool further, to create more quest variations, better level design tools, better variations in cultural assets, ability to include navigational maps, ability to include personalised assets, and cloud saves. Besides improving the tool, it is important to improve the trial design, by recruiting more participants with a more varied age group and educational levels. Moreover, when trying to measure learning impact it might be worthwhile to focus on the strength of serious games established in previous research. For example, my including questions about topics that are usually hard to visualize and memorize, the true potential of serious games might be realised which could lead to more distinct results in the learning impact compared to the control group. However, in this research the tool provided simple questing system that provide knowledge through text, which could partially explain why the learning impact was not statistically significant.

Chapter 6 Conclusion

6.1 Introduction

This section concludes the research and highlights the main research questions and how they were achieved. The research focused on cultural heritage and on developing an innovative solution that provides a new learning tool that is more immersive, speaks to younger generations and has a positive impact when it comes to cultural learning.

6.2 Outcome of research

The research questions and how they were answered are as follows:

1) **What are the prevailing methods utilized in teaching cultural aspects, and in what aspects do they demonstrate limitations or inadequacies?**

By reviewing the previous works done in the literature thoroughly various methods and tools related to cultural education were analyzed and the key points were noted down before any development work in this research was done. Interactive exhibitions, and a various array of serious games were researched that proved to be beneficial in cultural education. Learning pedagogies like the maker pedagogy and the multiliteracies pedagogy were ideal to be implemented in this research. The lack of 3D serious cultural game making tools was clear and this research aimed to fill that gap and explore this area further.

2) **How can the deficiency in 3D serious game maker tools tailored for cultural games be effectively addressed?**

By reviewing the literature, it was clear that there is a serious deficiency in 3D serious game maker tools in general, but even more specifically game maker tools for cultural serious games. To address the deficiency this research focused on developing an innovative educational tool that can integrate the maker ideology into cultural education. The tool allows the users to design their own serious cultural games and allow others to play them. To adhere to the learning theories, the development and design process made sure to integrate features that implement the suitable learning theories and gather feedback incrementally from experts and users to ensure that the tool is user-friendly, delivers the educational content efficiently, and most importantly servers its purpose as a cultural educational tool.

3) **What strategies are effective in designing a 3D serious game maker tool that resonates with younger generations, specifically in the context of cultural education?**

Previous research has solidified the concept that video games are a good medium for knowledge transfer and that if implemented correctly it could be an effective learning tool. However, designing a 3D serious game maker tool for cultural education is a challenge and careful consideration in the design phase is crucial to ensure that the final tool supports the main cause which is assisting in cultural education. By conducting various small user trials to understand the existing tools accompanied by interviews with experts, teachers, and future educators this research extracted important information that formulated strategies to design the 3D serious game maker tool. These were presented in the form of design guidelines and two versions are presented in this work. The first version is the one used to develop this tool which was crafted using the knowledge gained from the literature review and initial small user trials. The latter is a research output for future researchers and developers and incorporates knowledge from the interviews and further user trials.

4) **What is the user experience and degree of immersion reported by users when utilizing the designed tool?**

By conducting user trials with the final prototype of the tool, it was possible to analyze the user experience and degree of immersion based on the feedback from the users who participated in the trials. The feedback was mostly positive and after inferential analysis it was concluded that the positive difference between the test group and control group was statistically different indicating that the usage of the tool was the reason for the better user experience and immersion.

5) **What are the educational impacts of employing the designed tool for cultural education, particularly in terms of learning enhancement, memory retention, and knowledge acquisition?**

By conducting user trials with the final prototype and testing the impact on learning, various variables were calculated like learning gain, memory retention and knowledge retention. While the numerical differences between the test and control group indicated that the test group performed better due to the tool, the inferential analysis showed the that differences were not statistically significant. However, this inferential analysis might not be very accurate and representative of the actual result since they rely on a bigger user pool, and the participant count was too small. Regardless, improvements to the questionnaire design and increasing the number of participants is crucial when moving forward with this research.

6.3 Contribution

The central contribution of this research materializes around a new innovative way to teach culture in an engaging and immersive way that combines learning methods with gamification and blends it seamlessly into the maker movement. This innovative tool not only empowers users to craft immersive 3D games but also facilitates gameplay within the same framework. Its primary functionality lies in enabling users to seamlessly integrate cultural assets into their games, effortlessly adding quests to construct compelling narratives. The tool's distinctive feature lies in its user-friendly design, ensuring that individuals without technical knowledge in coding or game development can easily engage in the game creation process. The tool demonstrates how learning theories can be integrated into a modern tool for younger generations to use and encourages the use of modern learning pedagogies into modern educational tools.

The unique value of the tool is further amplified by its provision of a first-person, immersive design experience, offering users a novel perspective in game design. Beyond conventional game creation tools, this tool stands out by incorporating IoT functionality through RFID cards, enhancing user immersion. Additionally, the inclusion of a virtual chatbot, embodied by ChatGPT, serves as a valuable asset in assisting users with the storytelling aspect of game creation. This multifaceted tool is positioned not only as an accessible tool for game design enthusiasts but also as a potential supporting educational resource for classrooms. Furthermore, its application extends to exhibitions and museums, enriching cultural experiences through interactive and engaging game-based learning.

In the discussion, a crucial focus is placed on the choice of 3D design and its inherent advantages and disadvantages. Emphasizing the advantages of 3D design allows for a thorough understanding of the immersive and visually stimulating qualities that enhance user engagement. Simultaneously, addressing potential disadvantages sheds light on challenges and considerations that inform the decision-making process in utilizing 3D elements, contributing to a comprehensive assessment of the chosen design approach.

Other areas in this research that are yet to be investigated could potentially include the effect of designing other game types compared to 3D serious cultural games. For example, the designing of VR games or AR games, and how these technologies could change the results. Furthermore, more research is needed on how to integrate learning theories into game maker tools and how to make sure the key aspects of those learning theories are present in said tools. Utilizing advanced AI technologies to supervise the designing process to ensure the games created are historically accurate is also an interesting area to research that could make similar tools more efficient.

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APPENDIX A: Interviewee Details

Experts

Code	Gender	Age	Details
E1	Female	35 - 40	• Founder and owner of The Bendahari • Previous housekeeper of the Baba Nyonya Heritage Museum (3 years) • Aspires to create a hub that bridges foreigners, locals, designers, and entrepreneurs to engage, create and build ideas for historical Melaka • Suggested adding historical facts to assets in the game • Suggested that the toolkit could be used outside the classroom as well • Pointed out that the toolkit would be more useful if used after actually visiting the historical place
E2	Male	70 - 75	• Community leader of the Kristang community in Malacca • Aspires to preserve the Kristang cultural heritage • Tries to embrace new technologies to spread the message • Contributed personally by featuring in documentaries on the Kristang culture, including National Geographic • Believes games are the ways culture can reach the younger generations • Feels that language is the hardest aspect to preserve • Would like to include actual facts into the games

Teachers

Code	Gender	Age	Details
T1	Male	50 - 55	• Assistant Professor in the School of Education at University of Nottingham Malaysia

			• Experienced teacher for many years who also owns a school in his native country • Always trying to find innovative ways to teach the newer generations • Stressed out on the importance of including a guide for the students and the teachers to provide an organized way of using the toolkit • Believes it's important to have personalized elements where students can modify the assets, or add their own
T2	Female	35 - 40	• Associate Professor in the School of Education at University of Nottingham Malaysia • Has a background in media cultural studies, impact of use of media on culture and how people embrace culture • Her PhD was about reality TV and how people from different cultures can come together and work together (multiculturalism) • Aspires to use technology to preserve tradition and culture • Suggested adding interculturalism into the toolkit by arranging activities where different people from different cultures will use the toolkit to create one game • Suggested that the age group to use the toolkit could be as young as 10 years old
T3	Female	40 – 45	• School Principal in Tzu Chi International Schools • Previously worked in Rafflesia International Schools • Suggested working with a teacher to get the most relevant content • Stressed out on the importance of having a specific context for the toolkit to make sure the syllabus is being followed • Commented about how accurate assets in terms of similarity and accurate information will assist in learning and spark the student's interest

Students

Code	Gender	Age	Details
S1	Male	20 - 25	• First year education student in the University of Nottingham Malaysia • Aspires to be a high school teacher • Suggested adding a quest list, or a list of tasks to help students develop their games • Commented on the size of the crosshair, suggested making it smaller • Agreed that the toolkit would be better used individually, rather than just classrooms
S2	Male	20 - 25	• First year education student in the University of Nottingham Malaysia • Aspires to be an education researcher • Suggested the feature of being able to include multimedia elements into the toolkit like audio files or videos, to make the games more immersive • Commented that the toolkit could be used for a range of topics besides culture and that he would personally like to use to create levels and show it to his friends
S3	Male	35 – 40	• PhD education student in the University of Nottingham Malaysia • Very passionate about video games • Suggested that the students should be able to choose their own settings, instead of a default setting • Suggested adding personalization elements, like changing character’s names, adding logos, etc.

APPENDIX B: Questionnaires

Questionnaire 1: Analysis of existing 2D game authoring toolkit Scratch & Raspberry Pi

Question No.	**Question Description**
Q1	Please write down your age
Q2	What is your gender?
Q3	Have you used Scratch before? (any version)
Q4	Have you used Raspberry Pi before? (any model)
Q5	On a scale of 1-10, how hard was setting up the Pi and opening Scratch 3? 1 being Extremely easy and 10 being Extremely difficult
Q6	On a scale of 1-10, how hard was it to connect different sensors to the Pi and getting it to work with Scratch? 1 being Extremely easy and 10 being Extremely difficult
Q7	On a scale of 1-10, how hard was it to come up with a prototype idea using the Pi and Scratch? 1 being Extremely easy and 10 being Extremely difficult
Q8	On a scale of 1-10, how friendly is the user-interface of Scratch, especially the Pi extensions (blocks)? 1 being Extremely user-friendly and 10 being Extremely difficult to understand
Q9	On a scale of 1-10, how much benefit and value does incorporate sensors into games/projects you developed add? 1 being No benefits at all and 10 being Huge benefit
Q10	Please write your opinions/feedback/suggestions about how prototyping with the Pi and Scratch could be improved, what you did not like, etc.

Questionnaire 2: Feedback on inclusion of IoT into the tool

Question No.	**Question Description**
Q1	Do you think the cultural game authoring toolkit will help people share cultural heritage in an immersive way?
Q2	Do you think integrating IoT in the form of RFID cards in this cultural game authoring toolkit would be engaging?
Q3	Did you enjoy making a short game scene with the game authoring tool?
Q4	Would you like to use RFID cards as a form of IoT integration in your cultural game?
Q5	Would you want to use the RFID cards for performing actions in the game?
Q6	While designing your own game scene, did you find the game authoring tool hard to use?

Questionnaire 3: Second evaluation trial

Question No.	Question Description
Q1	On a scale of 1-5, how were the movement controls in the toolkit?
Q2	On a scale of 1-5, how was the Graphical Interface of the toolkit?
Q3	On a scale of 1-5, how was the space area given to design the game level?
Q4	On a scale of 1-5, how easy were the controls to design a game level? Was it easy to find which buttons to press to modify your design?
Q5	On a scale of 1-5, how was the saving and loading feature of the toolkit?
Q6	On a scale of 1-5, how easy was it to create quests and link them together to create your game flow?
Q7	On a scale of 1-5, how easy was it to switch between designing mode and playing mode? Was testing your game while designing it easy enough?
Q8	On a scale of 1-5, how useful was the story archive feature included in the toolkit to help you create stories?
Q9	On a scale of 1-5, how was the Graphical User Interface in the designed games?
Q10	On a scale of 1-5, how was the quest system while playing the game? Did it provide enough guidance for the players?
Q11	On a scale of 1-5, how easy were the controls to play the games?
Q12	On a scale of 1-5, were the number of objects available to design the game from adequate?
Q13	On a scale of 1-5, were there enough options to create the quests that you wanted or did you feel limited?
Q14	On a scale of 1-5, do you think the toolkit can create games that can effectively teach others about the Kristang culture?

Questionnaire 4a: Third evaluation trial (User experience and immersion)

Question No.	Question
Q1	How familiar are you with video games from a scale of 1 to 5, with 1 being not at all and 5 being very familiar?
Q2	In this experiment, you were asked to create a story based on the Kristang culture. Which tool did you use for this task?
Q3	Please rate your experience using the tool you selected for designing a story on a scale of 1 to 5, with 1 being very difficult and 5 being very easy.
Q4	How easy was it to translate your ideas into a story using the tool you selected, with 1 being very difficult and 5 being very easy?
Q5	How well do you think the tool helped you incorporate Kristang cultural elements into your story, with 1 being not at all and 5 being extremely?
Q6	Please rate the user interface of the tool in terms of user-friendliness on a scale of 1 to 5, with 1 being very unfriendly and 5 being very user-friendly.
Q7	Did you require assistance from the researcher(s) while designing your story, due to technical problems or confusion in understanding the task at hand?
Q8	Was the allocated time enough for you to design your story?
Q9	I lost myself in this experience
Q10	The time I spent using the tool just slipped away.
Q11	I was absorbed in this experience.
Q12	I felt frustrated while using this tool.
Q13	I found this tool confusing to use.
Q14	Using this tool was taxing.
Q15	This tool was attractive.
Q16	This tool was aesthetically appealing.
Q17	This tool appealed to my senses.
Q18	Using this tool was worthwhile.
Q19	My experience was rewarding.

Q20	I felt interested in this experience.

Questionnaire 4b: Third evaluation trial (Learning impact)

Question No.	Question
Q1	Who are the Kristang people?
Q2	What language did the Kristang people primarily speak?
Q3	Where do the Kristang people live?
Q4	Which option contains the most popular Kristang dishes?
Q5	What was the main way the Kristang people made a living?
Q6	What is the most common religion amongst the Kristang people?
Q7	What cultural activity were the Kristang known for?
Q8	During which years did the Kristang form?