Bridging Computer-Assisted Language Learning and Cultural Approaches: AI-Powered Game and VR Solutions for Less Commonly Taught Languages

Liang Xu

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Ollscoil Chathair
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Dublin City University

School of Computing

Supervisors

Dr. Monica Ward, Dublin City University

Dr. Elaine Uí Dhonnchadha, Trinity College Dublin

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Ph.D. is entirely my own work, that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

Sign: *Liang Xu* Student No.: 20214836 Date: 20/01/2025

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Contents

List of Figures

List of Tables

List of Abbreviations

AI	Artificial Intelligence
BERT	Bidirectional Encoder Representations from Transformers
CALL	Computer-Assisted Language Learning
CTTR	Corrected Type Token Ratio
DBR	Design-Based Research
DEG	Digital Educational Game
DGBLL	Digital Game-Based Language Learning
GenAI	Generative Artificial Intelligence
GPT	Generative Pre-trained Transformer
L1	First Language
L2	Second Language
LLMs	Large Language Models
LCTL	Less Commonly Taught Language
LSTM	Long Short-Term Memory
ML	Machine Learning
NLP	Natural Language Processing
PLMs	Pre-trained Language Models
POS	Part-of-Speech
SLA	Second Language Acquisition
TTR	Type Token Ratio
TTIG	Text-To-Image Generation
TTS	Text-To-Speech
VR	Virtual Reality
WDSEN	Words per Sentence
WTR	Word Type Ratio
ZPD	Zone of Proximal Development

Bridging Computer-Assisted Language Learning and Cultural Approaches: AI-Powered Game and VR Solutions for Less Commonly Taught Languages

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Abstract

Language learning is a multifaceted process that involves a complex interplay of cognitive, social and cultural factors. This complexity is particularly pronounced in the context of Less Commonly Taught Languages (LCTLs), where traditional pedagogical approaches often fall short. This thesis explores the integration of culturally informed approaches with advanced digital technologies to enhance the teaching and learning of LCTLs, focusing specifically on the Irish language as a case study.

The research presented here develops a Computer-Assisted Language Learning (CALL) system that leverages Digital Game-Based Language Learning (DGBLL) and Virtual Reality (VR). This system incorporates Artificial Intelligence (AI) techniques such as Natural Language Processing, Text-to-Image generation and Text-to-Speech synthesis to create immersive and culturally relevant learning environments. The study's primary goal is to investigate how these technologies can be employed to engage learners more effectively and support LCTLs.

Empirical evaluations conducted in primary school classrooms revealed that the CALL system enhances student engagement, motivation and language acquisition, as evidenced by positive feedback from both students and teachers. The research also highlights the adaptability of the developed tools for other low-resource and indigenous languages and their potential to be tailored to specific learner needs, including those with dyslexia. The findings of this study underscore the transformative potential of combining culturally informed approaches with cutting-edge technologies to address the unique challenges of language learning in LCTL contexts. By advancing the field of CALL, this research contributes insights into the preservation and revitalisation of indigenous languages.

Chapter 1

Introduction

1.1 Overview

Language learning has been a focus of research for many years. The process of acquiring a new language is complex and multifaceted, involving cognitive, social, and cultural dimensions (Qiao, 2024).

With the advent of digital technologies, the field of language learning has undergone significant transformations, leading to the rise of Computer-Assisted Language Learning (CALL) as a prominent field (Chapelle, 2010). CALL leverages digital tools and resources to provide interactive and engaging learning experiences, offering new opportunities for language acquisition. This technological shift has been particularly beneficial for Less Commonly Taught Languages (LCTLs), where resources and qualified teachers are often scarce (Godwin-Jones, 2013).

LCTLs encompass a broad and diverse category of languages that are not widely studied or commonly offered in educational institutions within certain regions or countries, according to the National Council of Less Commonly Taught Languages (NCOLCTL [1]). The designation of a language as 'less commonly taught' is inherently relative, reflecting the educational policies and language priorities of specific regions (Heidrich et al., 2024). This broad categorisation includes a wide range of languages, each with its unique challenges and needs, particularly in the context of computational resources and cultural vitality.

To focus this research, it is essential to narrow the scope from the broad category

[1] https://ncolctl.org

of LCTLs. From a computational perspective, the focus is on low-resource languages, while from a cultural viewpoint, the emphasis is on indigenous languages. Many languages that fit these categories are also minoritised, meaning they are spoken by communities that have been historically marginalised, leading to a decline in the language's use and status (UNESCO, 2022b). These languages are often at risk of disappearing, a phenomenon that has been widely documented and requires urgent action (Crystal, 2002). The disappearance of a language signifies not only the loss of a means of communication but also the erosion of cultural identity, traditional knowledge, and community cohesion (Harrison, 2008).

In response to the challenges faced by low-resource and indigenous languages, there is a need for language-independent tools that can be adapted to support the learning and revitalisation of these languages. Such tools are crucial because they can be tailored to meet the specific linguistic and cultural needs of various LCTLs, making them versatile and scalable solutions for language preservation. However, these tools are particularly scarce, making their development especially important in educational contexts.

This research takes the Irish language as a case study to explore and work towards adapting existing resources for low-resource and indigenous languages. Irish, a language with a rich cultural heritage native to Ireland but with limited computational resources (Blake, 1998; Lynn, 2022), provides an ideal context for this study. By focusing on Irish, this research aims to develop methodologies and tools that are not only effective for this particular language but also adaptable to other LCTLs with similar characteristics. The concept of language independence has been a guiding principle throughout this research, ensuring that the tools developed can be applied to other languages facing similar challenges, thus contributing to the sustainability of CALL (Ward, 2015a). For low-resource and indigenous languages, there is a need to develop language-independent tools, as a lack of inclusivity in language technology could further marginalise these languages, as noted by Joshi et al. (2020). By using the Irish language as a case study, this research not only seeks to address the needs of one language but also sets the foundation for broader applications that could benefit many other languages facing similar threats of decline.

Additionally, another important aspect of inclusivity in CALL involves addressing the needs of learners with specific challenges such as dyslexia and adapting educational technology and resources to meet their needs (Blume and Würffel, 2018). Dyslexia, a learning difficulty that affects reading and spelling, can affect the language learning journey (Rose, 2009). Including the considerations of dyslexic learners in the process of developing CALL is one of the highlights of this research, as technology can be a powerful tool to support these learners (Dogan and Delialioğlu, 2020). By recognising the diverse needs of learners, this research aims to create more inclusive learning environments, ensuring that students with varying challenges can access the resources. This consideration of inclusivity lays the groundwork for the discussion of CALL in later chapters, where specific adaptations for dyslexic learners are explored.

1.2 Motivation and Research Objectives

The Irish language, a low-resource and indigenous language of Ireland, holds a unique position as the first official language of the nation. Despite its official status, the daily use of Irish outside educational settings is limited (Walsh, 2022). Of those who use Irish daily, approximately one-third live in Gaeltacht regions—areas where Irish is traditionally spoken—while the remaining two-thirds are from communities where English predominates (CSO, 2022). This limited use underscores the challenges faced in revitalising the language, particularly among younger generations. Furthermore, the growth of the Irish language has been dependent on the education system, which has served as a critical avenue for language exposure and acquisition since the 1930s (Harris, 2007; Murtagh, 2007; Walsh, 2022).

In primary schools, the situation presents notable challenges (Batardière et al., 2023; Inspectorate, 2022). Research indicates a noticeable level of disengagement with the Irish language among primary school students, particularly in English-medium schools where most children are educated in Ireland (Devitt et al., 2018). This disengagement is caused by a variety of factors, including limited exposure to Irish outside the classroom and the perception that the language is less engaging compared to other subjects (Devitt et al., 2018; Martinez Sainz et al., 2023; McCoy et al., 2012). Murtagh (2007) observes that attitudes towards Irish language instruction tend to be neutral or even negative in English-medium schools. The work of Harris and Murtagh (1999) further highlighted that positive attitudes towards Irish are strongly correlated with higher levels of proficiency. However, as McCoy et al. (2012) pointed out, Irish is perceived less positively compared to other subjects such as reading and mathematics, with boys being particularly disengaged. This trend is alarming given the documented decline in Irish language proficiency among primary school students since the 1980s (Dalton, 2016; Harris et al., 2006).

In her research, Dalton (2016) advocates for innovative approaches to counteract this downward trend. There is a clear need for new and engaging tools that not only support language learning but also re-energise student engagement with Irish. This research is motivated by the urgent need to develop such tools, leveraging technology and cultural relevance to create a more engaging and effective language learning experience for Irish and other LCTLs.

Building on this context, the primary objective of this research is to support the teaching and learning of minoritised languages, such as Irish, in primary education as a foundational starting point (with plans to expand to older learners and other languages in the future), through the development of adaptable, culturally relevant, and technologically advanced CALL resources. This overarching goal is broken down into the following specific research objectives, which are addressed across Chapters 2 to 7:

- **Enhancing Engagement in Learning Low-Resource Languages:** The first objective is to explore creative and effective methods to engage students in learning LCTLs, with a particular focus on Irish.

- **Utilising Technology to Infuse Cultural and Contextual Knowledge:** The second objective is to integrate cultural and contextual knowledge into the LCTL learning process through the use of advanced technologies.
- **Developing and Evaluating Pedagogically Sound Resources for Irish:** The third objective is to develop and evaluate language learning resources that are pedagogically sound and specifically designed for LCTLs such as Irish.
- **Incorporating Cultural Approaches into Language Learning Tools:** The final objective is to explore the integration of cultural approaches into CALL tools for indigenous languages.

Through these objectives, this research aims to make a contribution to the field of language education, particularly in the context of low-resource and indigenous languages. By developing innovative, culturally relevant, and technologically advanced resources, the study seeks to address the challenges facing the Irish language and other LCTLs, ultimately supporting their revitalisation in the digital age.

1.3 Research Methodology

The methodological approach adopted in this research is rooted in the combination of technology and cultural approaches, as will be explained in later chapters, particularly in relation to the teaching and learning of LCTLs. The research methodology integrates Digital Game-based Language Learning (DGBLL), Virtual Reality (VR), and Artificial Intelligence (AI) to create immersive and culturally meaningful learning environments through the culturally informed approach of 'reconnecting to the spirit of language' (Napier and Whiskeyjack, 2021). These technologies are employed to enrich learners' cognitive, linguistic, and cultural engagement, particularly in the context of the Irish language.

1.3.1 Digital Game-Based Language Learning and Cipher

According to a report by Accenture (2021), the global gaming industry boasts nearly 3 billion gamers and generates over $300 billion in revenue, surpassing the combined earnings of the music and film industries. This massive growth has attracted the attention of major tech companies. Furthermore, a McKinsey report by Singer and D'Angelo (2020) highlights that major corporations such as Microsoft, Apple, Amazon, Google, Nvidia and Tencent are keen to capitalise on the expanding gaming sector, seeking novel approaches to connect with gamers and enhance the use of their platforms. Nvidia, for example, has evolved from its origins in producing computer graphics cards for gamers to becoming one of the most valuable companies globally, now a trillion-dollar company (McFarland, 2023). Its graphics processing units (GPUs) now power not only games but also advanced AI models, such as ChatGPT, showcasing the broader technological impact that gaming can have (McFarland, 2023), and how gaming can serve as a springboard for innovations in other fields. Given the profound impact of video games on technological advancements, harnessing their power for educational purposes, such as language learning, could revolutionise global education by offering immersive and engaging platforms for learners.

The use of Digital Game-Based Language Learning (DGBLL) in this research serves as a central methodological tool. The Cipher game series, developed and iteratively refined throughout the study, is an example of how games can be effectively repurposed for LCTL education. Cipher is the main vehicle for this research, serving as a DGBLL tool that aims to facilitate language acquisition, particularly for low-resource, indigenous languages such as Irish. The Cipher project explores the integration of digital gameplay into language learning environments, leveraging the engaging and interactive mechanics of a game to enhance motivation and learner engagement.

Cipher's game design focuses on providing a pedagogically sound experience while maintaining an enjoyable and engaging gameplay structure. The core narrative of the game revolves around decoding magical spells to unlock and access Irish myths, stories and folklore. This combination of language learning with cultural elements offers a multifaceted approach to language acquisition, blending cognitive challenges with the motivation of gaming. By embedding cultural narratives into the gameplay, Cipher not only promotes language proficiency but also encourages learners to connect with the Irish language within its rich cultural context.

At lower proficiency levels, learners are presented with familiar international fairy tales that serve as a linguistic bridge between their first language (L1) and the target language (Irish) (Haulman, 1985). These familiar narrative structures reduce cognitive load, allowing learners to focus on the game without being overwhelmed by unfamiliar content. As learners advance through the game, they encounter lesser-known Irish folklore and mythology. This progression not only reinforces language skills but also deepens their cultural immersion. The goal of the game is to help learners 'reconnect to the spirit of the language' (Napier and Whiskeyjack, 2021), a concept grounded in the cultural framework of this research. This resonates with the idea that language is more than a communication system—it is a vessel of cultural identity, values and history (Crystal, 2002; Walsh, 2022).

Cipher also addresses some of the issues related to Irish language learning, such as low motivation and engagement, especially in formal educational settings. By introducing gameplay elements, learners are encouraged to interact with the language in a less formal, more enjoyable environment, which contributes to greater retention and enthusiasm for learning. Feedback from both learners and teachers highlights Cipher's promise as a language learning tool that facilitates both linguistic proficiency and cultural reconnection.

The adaptive nature of the game allows it to be used in various educational contexts and tailored to the needs of diverse learners. Although Cipher is designed with Irish in mind, its language-independent structure enables it to be adapted for other low-resource and indigenous languages. This adaptability extends to learners with specific needs, such as those with dyslexia, making Cipher a versatile tool for promoting language learning in different contexts.

Cipher represents a fusion of cutting-edge digital technology and robust pedagogical strategies. It focuses on engaging learners through tasks that promote incidental language learning. This gamified approach makes language learning both interactive and culturally resonant by embedding Irish mythology into the game design, ensuring learners are exposed to both language and the cultural context in a meaningful way. The development of Cipher involved close collaboration with teachers to ensure that the game's content aligns with curriculum and educational standards. By working with teachers, the project ensured that the educational materials were pedagogically sound. In this way, Cipher serves as a model for how digital tools can be integrated into language learning to support not only proficiency but also cultural competence, which, as Acquah and Katz (2020) points out, is often neglected in digital learning games. By integrating advanced technology, cultural approaches, and pedagogical strategies, Cipher offers an engaging and culturally immersive learning experience. The game's adaptive and scalable design means it can be adapted to various language contexts, making it a valuable tool for broader efforts in language education. More details on Cipher can be found in Chapter 3.

1.3.2 Virtual Reality and Immersive Learning Environments

In the later stages of the research, the methodological focus shifts towards the integration of VR as a tool to improve the learning experience. VR offers a unique opportunity to create immersive environments that are both contextually rich and culturally meaningful.

VR places learners in virtual settings that represent cultural and historical aspects of the Irish language, culture and mythology. Some of these settings are mythological and non-realistic while others such as place names and landscapes, are designed to be realistic, offering a mixture of the real and unreal. This approach not only supports language acquisition but also deepens learners' engagement with the language's cultural heritage.

The incorporation of VR is particularly valuable in the context of LCTLs (Żammit, 2023), where digital resources are often limited (Godwin-Jones, 2013). The immersive nature of VR allows for the creation of dynamic and interactive learning scenarios that can adapt to the needs of different languages rooted in diverse cultures and mythology. This supports differentiated instruction and personalised learning pathways. By incorporating technology such as games, it helps make the language and culture more relevant to modern life and less antiquated, breathing new life into ancient mythology.

1.3.3 Cultural Approaches and CALL

The methodological framework of this thesis is further underpinned by cultural approaches. In the context of LCTLs, integrating cultural approaches with CALL and other supporting technologies (i.e., AI and VR) offers a powerful approach to language learning. This combined methodology not only addresses the cognitive and linguistic needs of learners but also fosters a deeper connection with the cultural and historical contexts of the language. This is especially important for learner motivation and engagement in the case of LCTLs where there is less utilitarian motivation.

As demonstrated in the development of the Cipher game series in later chapters, the integration of cultural elements into the game design goes beyond language instruction in traditional classrooms. For the purposes of this study, traditional classroom teaching refers to teacher-centred pedagogical approaches characterised by non-communicative activities and repetitive drills. Such methods have often been associated with lower student engagement and achievement in Irish, as discussed by Harris et al. (2006). By embedding Irish cultural narratives and cultural content into the gameplay, the research highlights the potential of CALL to not only teach minoritised languages but also to preserve and revitalise them by reconnecting learners with their cultural heritage.

1.3.4 Summary

In summary, the research approach of this thesis is characterised by the innovative integration of DGBLL, VR, and AI within a cultural framework. This approach underscores the importance of developing language learning tools that are both educationally effective and culturally resonant. The findings presented in the subsequent chapters demonstrate the potential of CALL methodologies to enhance LCTL learning, not only by improving language proficiency but also by fostering meaningful connections to the language's cultural heritage.

1.4 Thesis Roadmap

This thesis systematically addresses the research objectives, progressing from the conceptualisation of the problem to the investigation, execution of each objective, and ultimately to the conclusions and implications of the findings.

Chapter 2 lays the foundation for the research by presenting the conceptual framework of the study. This chapter provides a review of the relevant literature, identifying key gaps and establishing the theoretical underpinnings that guide the research. The chapter concludes with the formulation of four specific research questions, each mapping to one of the research objectives. This framework sets the stage for the subsequent chapters, ensuring that each part of the thesis contributes to the overall research aims.

Chapter 3 provides an overview of the research process, outlining the different stages of the study's development. This chapter traces the evolution of the research design and methodology, emphasising the principles of Design-Based Research (DBR). The DBR approach offers insights into the iterative process that shaped the project. It also highlights the practical considerations and decisions undertaken to ensure the research remained aligned with its objectives, serving as a roadmap for how the study was conducted. This alignment supports the third research objective by contributing to the development of pedagogically sound resources for Irish.

Chapter 4 addresses the first research objective: Enhancing Engagement in Learning Low-Resource Languages. This chapter focuses on the adaptation of existing game resources, originally designed for dominant languages, to meet the needs of LCTLs such as Irish. The chapter explores how these adaptations can make language learning more interactive, thereby fostering greater engagement and motivation among learners.

Chapter 5 discusses the second research objective: Integrating Cultural and Contextual Knowledge through Technology. This chapter explores the application of advanced technologies, specifically Artificial Intelligence (AI), in creating immersive and culturally enriched learning environments. The chapter examines how these technologies can support language learning while simultaneously deepening learners' connections to the cultural and historical contexts of the language. Although VR is discussed in detail in Chapter 7, a brief overview is also included in Chapter 5 as part of the technological approaches employed in this study.

Chapter 6 contributes to the third research objective by focusing on the evaluation phase of pedagogically sound resources for Irish. This chapter explores the impact of DGBLL resources on learning outcomes. The emphasis is on ensuring that these resources not only engage learners but also meet educational standards and promote effective language acquisition. The chapter offers a critical evaluation of the pedagogical effectiveness of the tools developed, providing information on the creation of language learning resources for LCTLs.

Chapter 7 focuses on the fourth research objective: Incorporating Cultural Approaches into Language Learning. This chapter examines how elements of Irish folklore and mythology can be enhanced within the game environment to foster a deeper, more meaningful engagement with the language. The chapter highlights the potential of culturally rich content to support language learning and reconnect learners with their cultural heritage. The use of VR is particularly emphasised in this chapter as a tool to enhance cultural approaches, providing an immersive experience that reinforces the cultural dimensions of language learning.

Finally, Chapter 8 brings together the findings from the previous chapters in the Conclusion. It revisits the research objectives and questions, summarises the key findings, and discusses their implications for the fields of CALL and LCTL education. The chapter also outlines the limitations of the research and suggests directions for future research, offering a reflection on the contributions of the thesis to the academic discourse on language learning and technology.

1.5 Publications

Several publications arise from this PhD research, which are highlighted here for clarity. Table 1.1 provides a clear mapping between the papers and the chapters in the thesis. The content of the thesis has been published in the following papers.

Publication	**Chapter/Reference**
Liang Xu, Jenny Thomson, Elaine Uí Dhonnchadha, and Monica Ward. Learner-oriented game design: The evolution of Cipher. In Proceedings of the *2024 IEEE CTSoc Gaming, Entertainment, and Media Conference (GEM)*, pages 1–6, 2024. IEEE. (Poster presentation)	Chapter 2, 3 (Xu et al., 2024c)
Liang Xu, Elaine Uí Dhonnchadha, and Monica Ward. User experience study of "Cipher: Faoi Gheasa", a digital educational game for language learning and student engagement. In *Proceedings of the 2nd Workshop on Games Systems within the 13th ACM Multimedia Systems Conference*, pages 5–8, Athlone, Ireland, 2022. (Oral presentation)	Chapter 2, 4 (Xu et al., 2022)

Liang Xu, Mark Andrade, Elaine Uí Dhonnchadha, and Monica Ward. Cipher in classrooms: Evaluating digital game-based language learning for Irish vocabulary acquisition. In *Proceedings of the 13th International Games and Learning Alliance (GALA) Conference*, pages 25–35 Berlin, Germany, 2024. (Oral presentation)	Chapter 2, 6 (Xu et al., 2024a)
Liang Xu, Elaine Uí Dhonnchadha, and Monica Ward. Exploring the synergies between technology and socio-cultural approaches in computer-assisted language learning. In *Proceedings of the 10th Language & Technology Conference*, pages 337–342, Poznań, Poland, 2023. (Oral presentation)	Chapter 2, 7 (Xu et al., 2023b)
Liang Xu, Haoyang Du, Songkai Jia, Mark Andrade, Cathy Ennis, Elaine Uí Dhonnchadha, and Monica Ward. Mythology meets technology: Transforming a 2D game into a virtual reality journey for language reconnection. In *Proceedings of the IEEE 3rd International Conference on Intelligent Reality (ICIR 2024)*. Coimbra, Portugal, 2024. (Poster presentation)	Chapter 2, 7 (Xu et al., 2024b)
Liang Xu, Elaine Uí Dhonnchadha, and Monica Ward. Harnessing the power of images in CALL: AI image generation for context specific visual aids in less commonly taught languages. In *Proceedings of the EUROCALL 2023 Short Papers*, pages 92–97, Reykjavik, Iceland, 2023. (Oral presentation, **Best Student Paper Award**)	Chapter 2 5 (Xu et al., 2023a)

Leona Mc Cahill, Thomas Baltazar, Sally Bruen, **Liang Xu**, Monica Ward, Elaine Uí Dhonnchadha, and Jennifer Foster. Exploring text classification for enhancing digital game-based language learning for Irish. In *Proceedings of the 3rd Annual Meeting of the Special Interest Group on Under-resourced Languages within LREC-COLING 2024*, pages 90–96, Turin, Italy, 2024. (Poster presentation)	Chatper 2, 5 (Mc Cahill et al., 2024)
Monica Ward, **Liang Xu**, and Elaine Uí Dhonnchadha. Enhancing language learning for dyslexic learners: Integrating text-to-speech AI in CALL. In *Proceedings of EuroCALL 2024 short papers*, Trnava, Slovakia, 2024. (Oral presentation)	Chapter 2, 5 (Ward et al., 2024a)
Monica Ward, **Liang Xu**, and Elaine Uí Dhonnchadha. Enhancing human-centric CALL through AI innovations. In *Proceedings of EuroCALL 2024 short papers*, Trnava, Slovakia, 2024. (Oral presentation)	Chapter 2, 5 (Ward et al., 2024b)
Monica Ward, **Liang Xu**, and Elaine Uí Dhonnchadha. How NLP can strengthen digital game based language learning resources for less resourced languages. In *Proceedings of the 9th Workshop on Games and Natural Language Processing within the 13th Language Resources and Evaluation Conference*, pages 40–48, Marseille, France, 2022. (Oral presentation)	Chapter 4, 5 (Ward et al., 2022)

Elaine Uí Dhonnchadha, Sally Bruen, **Liang Xu**, and Monica Ward. Empowering adaptive digital game-based language learning for under-resourced languages through text analysis. In *Proceedings of the 10th Workshop on Games and Natural Language Processing @ LREC-COLING 2024*, pages 6–13, Turin, Italy, 2024. (Oral presentation)	Chater 5 (Uí Dhonnchadha et al., 2024)
Elaine Uí Dhonnchadha, Monica Ward, and **Liang Xu**. Cipher—Faoi Gheasa: A game-with-a-purpose for Irish. In *Proceedings of the 4th Celtic Language Technology Workshop within LREC2022*, pages 77–84, Marseille, France, 2022. (Poster presentation)	Chapter 5 (Uí Dhonnchadha et al., 2022)
Monica Ward, Elaine Uí Dhonnchadha, Jennifer McGarry, and **Liang Xu**. Co-creating CALL content—does it work? Goldilocks compromise or Cruella chaos? In *Proceedings of the EUROCALL 2023 Short Papers*, pages 165–170, Reykjavik, Iceland, 2023. (Oral presentation)	Chapter 3 (Ward et al., 2023)

Table 1.1: Mapping publications to thesis content.

Chapter 2

Conceptual Framework: Using Advanced Technology to Bridge CALL and Culturally Informed Approaches for LCTLs

2.1 CALL for Less Commonly Taught Languages

2.1.1 An Overview of CALL and LCTLs

Computer-Assisted Language Learning (CALL) has been an active area of research and application since its emergence in the 1960s (Levy, 1997). Significant advancements have been made since the early 21st century, with CALL now encompassing a broad range of tools and resources designed to support language teaching and learning across fundamental skills: reading, writing, listening, and speaking. Popular applications like Duolingo, Memrise, and Babbel are examples of how CALL has been integrated into mainstream language learning. However, most CALL research and resource development have primarily focused on commonly taught languages, particularly English, which cater to a global population of approximately 1.5 billion learners (Dyvik, 2023). This focus is driven by the high demand for English language learning, resulting in a wealth of resources for English and, to a lesser extent, other widely spoken languages such as Spanish, French and

German.

In contrast, there are fewer resources for Less Commonly Taught Languages (LCTLs) (Ward, 2015b). LCTLs can range from languages with a large number of speakers such as Chinese and Arabic to languages with fewer speakers but still widely spoken in their country of origin such as Polish and Thai. The term also covers minoritised or regional languages like Catalan and endangered languages like North Saami (Ward, 2018). As mentioned in Chapter 1, to narrow the scope, this research focuses on low-resource languages from a computational perspective, while from a cultural perspective, it focuses on indigenous languages. Many languages that fall into both categories are also minoritised languages. According to Aguilar-Amat and Santamaria (2000), minoritised languages are those that have been marginalised or subordinated due to factors such as historical, political or socio-economic circumstances, not merely because of the number of speakers. Minoritised languages are often confused with minority languages. Minority languages, on the other hand, are mainly defined by having a small number of speakers (Aguilar-Amat and Santamaria, 2000). Their research highlights that the term 'minority' is problematic because it focuses only on speaker numbers, ignoring that many so-called minority languages face challenges due to historical and social factors, not just population size.

The case study language in this research, Irish, fits into both of the above categories, computationally and culturally, and it is also a minoritised language. The development of CALL resources for LCTLs is challenging. This is mainly because CALL resources are difficult to develop and should ideally have a multidisciplinary team of educators, linguists, language teachers, software developers, user interface designers and language learners involved in their development (Ward, 2006), all of which may be in short supply for LCTLs. This is particularly true for minoritised languages. The difficulty in developing CALL resources stems from several challenges these languages face, including the lack of printed and online resources in the language, dialectal issues, lack of societal support, lack of quality language documentation, lack of an active speaker community or native speakers, competent linguists and qualified teachers (Godwin-Jones, 2013; Ward, 2015b).

The scarcity of CALL resources for LCTLs perpetuates a vicious cycle. Without CALL, learners of LCTLs and minoritised languages cannot enjoy the advantage of CALL which includes easier and cheaper access to learning materials. Furthermore, it is more challenging for learners to access authentic language resources, leading to lower motivation and fewer learners overall. For example, simply wanting to hear their languages being spoken can be an issue as learners of the languages may not have native speakers near them or some of these languages may not even have many speakers left. Therefore, learners have more difficulty learning the languages, and then there will be fewer learners of these languages. This, in turn, reduces the demand for and development of CALL resources. For instance, the Irish language, despite its official status in Ireland, is also an LCTL internationally. Although there is a large Irish diaspora, the global number of Irish learners remains small, further complicating efforts to develop CALL resources tailored to this language (Ward, 2015b).

Furthermore, motivation is a big challenge for LCTL learners. Learners of these languages are often less motivated both intrinsically and extrinsically for various reasons. Increasing motivation among learners of LCLTs is crucial, recognising that the unique social, cultural and linguistic contexts of LCTLs require tailored strategies to sustain and enhance learner engagement. Therefore, to address these challenges, the LCLT CALL researchers are creative and have adopted approaches to leverage existing technology and adapt it to the specific needs of LCTLs (Millour and Fort, 2020; Purgina et al., 2017).

2.1.2 Motivation in Language Learning

Motivation is essential for language learners in the process of language learning. It is often why learners choose to learn a language and it also helps learners continue to study the language. There has been a lot of focus on motivation in the language learning literature (Oxford and Shearin, 1994; Hattie and Learning, 2009; Dörnyei and Ushioda, 2021; Lightbown and Spada, 2021; Ueno, 2005). According to Ueno (2005), motivation is divided into three stages. The first stage is the initial reasons for doing something. The second stage is the decision to do something and the last stage is to continue to make an effort (Ueno, 2005). The process reflects the motivation of some language learners. In this section, various motivation theories are explored and integrated with language learning, drawing on research in the field.

Before diving into the theories, it is important to specify two definitions of language learning. According to Oxford and Shearin (1994), a second language (L2) is a language that is learnt in a place where the language is used mainly in daily life (e.g., Chinese people learn English in an English-speaking country), while a foreign language is a language that is learnt in the area where the language is not typically used, instead people use another language (e.g., Chinese people learn English in China).

There are different reasons why people learn a language. Some people are interested in the culture of the target language or they would like to speak to people from the country and make friends with them. This is an integrative motivation (Oxford and Shearin, 1994; Ushioda, 2011). Others may learn a language because they plan to start a business in the country of the target language or study abroad. This is an instrumental motivation (Oxford and Shearin, 1994; Ushioda, 2011). In Dörnyei (1990)'s study, he states that integrative motivation is more relevant for L2 learners than foreign language learners, and it may help people reach the intermediate level in the target language learning (Dörnyei, 1990). Furthermore, integrative motivation is also useful in language classes, which improves class performance and student satisfaction, according to the study by Gliksman et al. (1982). In contrast, instrumental motivation is more meaningful for foreign language learners than for second language learners (Dörnyei, 1990). It plays an important role in the target language learning for students at the intermediate level or below. Another essential factor, pointed out by Dörnyei (1990), is the need for achievement or expectancy-value. In this theory, learners are motivated by the expectancy and desired learning outcomes (Wen, 1997).

The intrinsic/extrinsic motivation theory is built on the basis of the self-determination theory (Ueno, 2005), which suggests human behaviours are self-determined (Deci and Ryan, 1985). Intrinsic motivation is driven by the inherent rewards or punishments that people may experience from the activity itself, while extrinsic motivation is driven by external rewards or punishments (Ueno, 2005), such as studying a language to pass exams or to meet parents' expectations (Oxford and Shearin, 1994). Instrumental motivation is considered a type of extrinsic motivation (Schmidt et al., 1996). Integrative and intrinsic motivation, which share some overlap, were both described by Noels et al. (1999) as reflecting a positive attitude towards learning.

2.1.3 Motivation in the Irish Context

Language learning can be both engaging and enjoyable, yet for many learners, particularly those who are required to study a language, it can become an uncomfortable, monotonous, and unenjoyable experience. This issue is prevalent among L2 learners, especially when the language is a compulsory part of the education system. Among these learners are those studying English as a second language, who often face several challenges due to their reluctance to engage fully. Protheroe (2004) observes that such reluctant learners tend to avoid tasks and challenges, even when they have the capability to excel. Sanacore (2007) underscores the importance of fostering intrinsic motivation in these learners, suggesting that creating a learning environment that is both encouraging and challenging is crucial. He cautions against oversimplifying content, arguing that even novice language learners benefit from engaging in challenging activities. Additionally, Sanacore (2007) advocates for offering students choices in their learning processes, as this autonomy can lead to increased cognitive flexibility, high task interest, positive emotions, creativity and persistence (Coyne et al., 2007; Deci and Ryan, 1985).

Active participation in classroom activities is also essential (Sanacore, 2007), as it enhances intrinsic motivation and cultivates a passion for learning, making educational experiences more enjoyable and fruitful for students.

In Ireland, where Irish is one of the three official languages (alongside English and Irish Sign Language), only 2 % of the population speaks it daily outside the education system (CSO, 2022). Irish is a compulsory subject in both primary and post-primary schools, but students often lack the motivation to study the language. This lack of motivation can make Irish lessons feel more like a chore than an enjoyable learning experience. A large-scale study conducted by Harris et al. (2006) in primary schools found that while students had a positive attitude toward the Irish language itself, their motivation to learn it was less favourable. Furthermore, students perceived Irish lessons and materials as outdated and repetitive (Harris et al., 2006). This trend persists in post-primary education, with studies indicating that students' motivation to learn Irish remains low (Barnes et al., 2024; Murtagh, 2007).

Compounding this issue is the fact that most teachers, who are not native speakers themselves, bear the responsibility for Irish language education, as many parents are unable to assist their children with Irish homework (Harris et al., 2006; Martinez Sainz et al., 2023). Interactive resources for teaching Irish are scarce, and although there are standalone and freely accessible online learning resources like Séideán Sí [1], these can be limited in scope. Most Irish textbooks come with supplementary digital editions and resources, but these are typically subscription-based, which can limit parental or home access. Unsurprisingly, Irish was regarded as the most difficult subject in both primary and post-primary education (Barnes et al., 2024; Martinez Sainz et al., 2023; Smyth, 2006).

Although Irish holds a special position in Ireland's language policies (Gallagher, 2021; Walsh, 2022), it is not classified as a Modern Foreign Language (MFL) in the Irish school curriculum (Barnes et al., 2024; Ward, 2007), unlike languages such as Spanish, German, and French. This distinction means that Irish may not benefit

[1] `https://www.seideansi.ie`

from many pedagogical innovations that have been successfully implemented in the MFL field. For example, MFL teachers have improved their language competence for teaching in recent years through the Erasmus programme (Gallagher, 2021). These innovations could make learning Irish more engaging and personalised for students (Duibhir and Cummins, 2012). A 2022 report by Department of Education inspectors highlighted the need for more engaging Irish language learning activities, noting an overreliance on translation from Irish to English and a lack of fun, engaging experiences in the classroom (Inspectorate, 2022). To address these issues, it is essential to provide challenging and fun learning activities, offer student choice, and encourage active learning. One promising approach to achieving these goals is through the use of Digital Game-Based Language Learning (DGBLL) designed specifically for Irish, as detailed in the project.

Motivation has long been recognised as a critical factor in successful language learning. Gardner and Lambert (1972) hypothesised that learner motivation plays a crucial role in L2 acquisition, distinguishing between instrumental motivation—driven by practical and financial incentives—and integrative motivation, which is inspired by positive feelings towards the community that speaks the language (Dörnyei and Ushioda, 2021; Gardner, 1985). In the context of learning a minoritised L2 language like Irish, where English is the dominant L1, fostering integrative motivation is particularly important. Encouraging positive attitudes towards the Irish language and culture is key to successful language acquisition.

One innovative approach to enhancing integrative motivation involves the use of games and Virtual Reality (VR), a gaming experience that immerses learners in the rich tapestry of Irish mythology and folklore. In this research, games and VR are used to expose users to the folklore and mythology of the target language, aiming to raise their cultural and language awareness. This approach is intended to help learners reconnect to the spirit of the language (see Section 2.2.2), thereby increasing their intrinsic motivation. Research has shown that games, especially VR games, are effective in raising cultural awareness and preserving heritage (Anderson et al., 2010;

Cheng et al., 2017; Tafazoli, 2024), as VR provides a uniquely immersive experience.

Additionally, game rewards offer learners extrinsic motivation, a strategy that has been employed in various language learning applications, such as Duolingo (Saleem et al., 2022). The challenging game mechanics and engaging content of Cipher and VR create a positive and exciting environment that encourages learners to reconnect with the Irish language and culture. Mythological stories and heroes have a timeless appeal, as evidenced by the popularity of the Marvel Cinematic Universe, which draws heavily on Norse mythology, and the 'Percy Jackson and the Olympians' series, rooted in Greek mythology (MCU, n.d.; Riordan, 2005). Similarly, the Cipher project taps into the magical and heroic world of Irish mythology, enticing learners from diverse backgrounds to engage with the language. This connection to the cultural and mythological heritage of the language fosters integrative motivation by increasing interest in the culture, encouraging learners to become part of the Irish-speaking community, and sustaining their interest in the language—essential components of integrative motivation in L2 acquisition. Meanwhile, game rewards and punishments provide instrumental motivation, offering extrinsic incentives to keep learners engaged.

2.1.4 Challenges in Irish Language Learning

The teaching and learning of Irish arguably face significant pedagogical challenges, compounded by several factors that collectively diminish student motivation and engagement with the language.

The social and cultural role of Irish in Ireland is complex. While there is national pride in the language and many parents support it, their negative memories of learning Irish and limited ability to help their children impact their children's motivation to learn the subject (Harris et al., 2006; Martinez Sainz et al., 2023). As Devitt et al. (2018) pointed out, it is important to differentiate between attitudes towards the Irish language and attitudes towards learning it. Furthermore, the lack of a utilitarian purpose for learning Irish—since all Irish speakers are bilingual in English—also discourages students from investing effort in mastering the language. This is reflected in public opinion on learning the language, with post-primary students considering Irish the least useful subject (Barnes et al., 2024; Smyth, 2006).

Moreover, most primary school teachers are not native speakers of Irish and often lack confidence in their own language abilities (Inspectorate, 2007, 2013, 2022). Notably, Irish-medium schools have encountered difficulties in finding teachers competent in Irish (Barnes et al., 2024; Department of Education, 2022). Teachers' linguistic competence and attitudes have a significant impact on students' achievement and motivation in Irish (Harris et al., 2006). Harris et al. (2006) also found that teachers' attitudes towards teaching and learning Irish had declined with 25% of teachers viewing their proficiency in Irish as inadequate to teach the subject. This lack of confidence in the language can lead to suboptimal teaching practices, as noted in a report on the teaching and learning of Irish (Inspectorate, 2007). While teachers play a crucial role in motivating students to learn a language, the decline in attitudes and confidence among teachers about Irish is creating challenges (Duibhir and Harris, 2023; Harris, 2007; Martinez Sainz et al., 2023).

One area where this causes difficulties for learners is the differences between English and Irish orthography. English orthography is very irregular and schoolchildren spend a lot of class time in the early years of primary school learning sound/orthography combinations. Irish orthography, though complex, is relatively regular (Hickey and Stenson, 2011). However, there is a general perception that it is irregular and not transparent (Ward, 2016). Teachers often lack awareness of the logic behind patterns in Irish spelling and, as a result, do not convey them to students. This mismatch between Irish letter-sound correspondences and learners' expectations, shaped by other languages like English, leaves students with gaps in knowledge, which they tend to fill with intuitions from English. The transfer of orthographic knowledge from English to Irish often leads to incorrect pronunciations and a misunderstanding of Irish spelling rules. This further diminishes their motivation. For example, the Irish word 'seachtain' ('week') could be pronounced as 'say-ach- tayne' on first reading by an L1 English speaker. However, the actual pronunciation is closer to 'shokht-en' or 'shocht-en'(ʃaxtˠənʲ). The 'e' after the 's' in seachtain indicates that the 's' should be pronounced as /ʃ/ ('sh') and the 'e' itself does not reflect an actual vowel. Irish language learners are generally not taught about these types of pattern and thus often mispronounce Irish words on first sight. Irish language learners often 'ignore' the accents on vowels, as they do not understand their importance. An accent lengthens a vowel, so that 'á' is pronounced /ɑː/ 'aw', whereas 'a' is pronounced /ə/ 'ah'. 'Bá' means 'bay' whereas 'ba' can mean 'cows'. Another challenging feature for Irish learners is the presence of unusual combinations of letters, especially when marking initial mutations such as eclipsis at the start of words, for example, bp, mb, bhf, dt, nd, gc, and ng. Hickey and Stenson (2011, 2016) recommend that these be taught explicitly but unfortunately this does not always happen. There are also digraph combinations that can cause difficulties for students including ei, ea(i), eo(i), ae(i), and ao(i), as well as unstressed final syllables e.g., -(a)igh, -(a)idh, amh, - adh. These letter combinations may seem confusing to students, but there is a logic behind them. If learners understood these patterns better, it would enhance their comprehension and enjoyment of reading texts in Irish, or at the very least, reduce the challenges they face. Table 2.1 summarises some of the orthographical challenges faced by Irish language learners.

Issue	**Example**
Different orthography from English	Seachtain - 'se' indicates 's' should be pronounced 'sh'
Accents indicate vowel length	mo 'my' is different from mó 'more'
Unusual consonant combinations due to eclipsis	bp, mb, bhf, dt, nd, gc, and ng
Unusual digraph combinations	ei, ea(i), eo(i), ae(i), and ao(i)
Unstressed final syllables	-(a)igh, -(a)idh, -amh, -adh

Table 2.1: Examples of Irish orthographic issues.

Another aspect of Irish grammar which receives surprisingly little attention is noun gender. Irish has two grammatical genders for nouns – masculine and feminine, which have wide ranging consequences in the grammar and spelling. It is not obvious from the word what gender a particular noun has – students should learn it when they encounter a new noun. However, often this gender information is not made explicit to learners and they will be unaware of this feature of the language. This is unfortunate as this information is important for the construction of grammatically correct sentences in the language. Many initial mutations and modifier agreements vary according to the gender of the noun. In Cipher: Faoi Gheasa, particular attention is given to spelling, including initial mutations, the gender of nouns and accents on vowels.

In addition to these challenges, the morphological complexity of Irish, including features such as initial mutations (e.g., lenition and eclipsis) and digraph combinations, presents difficulties for learners (Hickey and Stenson, 2011). For instance, lenition involves the softening of consonant sounds, often marked by the addition of an 'h' after the consonant in writing (e.g., 'bó' becomes 'bhó'). Eclipsis, on the other hand, replaces the initial consonant with a voiced consonant (e.g., 'bó' becomes 'mbó'). These complexities are often not taught explicitly, leaving students confused and frustrated, which further diminishes their motivation. Last but not least, the limited availability of digital resources exacerbates these issues, as few engaging, pedagogically sound tools are available to support the learning process. For example, learners of Irish can benefit from increased motivation through the use of digital resources, such as language-focused games (Cornillie et al., 2012). However, the availability of such resources for Irish is limited (Lynn, 2022; Ward, 2015b), creating additional barriers to effective language acquisition.

Early success is crucial in any language learning (Guskey, 1999). However, negative early experiences with Irish can discourage students from continuing their studies. Those who have prior experience of learning a language know that it can be challenging at times and requires a degree of resilience and that it is important to persevere when difficulties are encountered. For most first language (L1) English primary school students in Ireland, their first exposure to another language is when they start learning Irish in primary school (Department of Education, 2019).

This critical first experience can have an impact on future language learning. For example, if a student has a negative experience learning Irish, this could affect their enthusiasm or self-confidence in learning another language. The combination of morphological complexity, poor teaching methods, and limited resources creates an environment where students are less likely to achieve early success, leading to decreased motivation. Research has called for new methods to reverse the downward trend of Irish learning (Dalton, 2016). Table 2.2 summarises the challenges associated with teaching and learning Irish in schools.

Challenge	**Explanation**
Complex social and cultural role	Parents are proud of language, but may have unhappy memories of learning it themselves.
No utilitarian value	All L1 Irish speakers are also bilingual in English
Teachers are not native speakers	Teachers lack confidence when teaching the language
Orthography	Letter-sound correspondence is not taught effectively
Morphologically complex language	Lenition and eclipsis (word initial mutations) create challenges for students
Lack of digital resources	Few digital resources and games to motivate learners

Table 2.2: The challenges of teaching and learning Irish in Irish schools.

Although some of the challenges discussed are unique to Irish, there are similarities between Irish and other LCTLs within the language learning landscape. A clear parallel is the scarcity of curriculum-aligned, pedagogically sound digital resources, particularly those focused on language learning. Currently, there appears to be a scarcity of readily available and curriculum-aligned digital games for Irish that are suitable for classroom use. As noted by Ellis (2010), Second Language Acquisition (SLA) research has improved language teaching methodologies, particularly for widely taught languages such as English and Spanish. However, Irish has not fully benefited from these advancements, and there remains a pressing need for resources that make learning Irish enjoyable and effective. Although some digital resources for Irish, such as ABAIR (Ní Chasaide et al., 2017) and gaBERT (Barry et al., 2021), are available, they are not widely known and are underutilised.

2.1.5 Irish CALL

The development of CALL resources could provide many benefits. However, for low-resource languages like Irish, creating such resources faces substantial challenges, due to limited financial, technical and linguistic resources (Ní Chasaide et al., 2022). Despite these obstacles, there is a growing appetite for CALL resources, particularly game-like applications to support language learning in the Irish context. Several notable CALL initiatives have been developed for Irish, demonstrating innovative approaches to addressing the needs of Irish learners.

BabelAR is an Augmented Reality (AR) game designed to foster multilingual competence through interactive language-based tasks and collaborative problem-solving (VirtuLApp, n.d.). It engages primary school students by incorporating multiple languages, including Irish, thereby promoting language awareness and multilingualism (Buendgens-Kosten, 2022; Waterzooi, 2021). This AR-based approach reflects a growing interest in leveraging emerging technologies to make language learning more engaging and contextually relevant.

WordBricks adopts a visually interactive approach to language learning, using coloured and shaped blocks representing parts of speech to facilitate grammar acquisition. Initially developed for English and subsequently adapted for Irish, the app supports learners in assembling grammatically correct sentences. This approach is suited for primary school students, aligning with classroom practices and offering game-like features to enhance engagement (Purgina et al., 2017; Ward et al., 2019a).

Fáilte go TCD is a 3D game-based CALL platform designed to teach Irish through a virtual world modelled on various scenes within Trinity College Dublin (TCD). It integrates synthetic speech powered by the ABAIR Text-To-Speech (TTS) system (Ní Chasaide et al., 2017), creating contextually relevant educational experiences. The combination of animated 3D characters and dialogue interactions has received positive feedback, particularly regarding the acceptance of Irish synthetic voices (Ní Chiaráin and Ní Chasaide, 2015). Similarly, *Digichaint*, a game adapted from *The Language Trap* (Peirce and Wade, 2010), originally designed to teach German. It also uses ABAIR to provide an engaging virtual learning environment for Irish language learners, emphasising interactive dialogues and engaging gameplay (Ní Chiaráin and Ní Chasaide, 2016b).

Three-Dimensional Virtual Environments (3DVEs) are digital spaces designed to simulate real-world or imaginary settings (Dickey, 2005). For instance, *Fáilte go TCD* features a virtual replica of TCD campus. Dalton and Devitt (2016) explored the use of 3DVEs to enhance task-based language learning for primary school students studying Irish. Their findings suggest that 3DVEs can re-energise Irish language learning by fostering authentic language communities and encouraging meaningful communication. *GaeltechVR*, on the other hand, examined the impact of VR on adult learners of Irish. Collins et al. (2019) highlighted how VR platforms influence learners' situated identity and engagement within a virtual context. These initiatives underscore the potential of emerging technologies in creating interactive and immersive CALL experiences for Irish learners. These studies will be discussed in detail in the relevant sections of this chapter.

Despite the promising developments discussed above, research on CALL for Irish remains sparse. More importantly, existing studies seldom evaluate the learning gains associated with these tools, leaving a gap in understanding their pedagogical efficacy. The lack of comprehensive learning evaluations of game-based CALL for Irish underscores the need for further investigation into their impact on language acquisition and learning outcomes.

This research project, Cipher, aims to harness the motivational and engaging elements of digital games to enhance both gameplay and language learning for Irish learners. The study also explores the pedagogical impact of the game on learning outcomes, contributing to the growing body of research on CALL tools for Irish.

2.1.6 Dyslexia and CALL

Dyslexia, though not specific to LCTLs, is an important consideration when addressing learners' needs in CALL. Developmental dyslexia is a specific learning difficulty that affects the accuracy and efficiency of word reading and spelling (Rose, 2009). It is characterised by challenges in identifying speech sounds and understanding their relationship to letters and words, impacting learners across a broad spectrum of reading abilities. Importantly, dyslexia is not tied to intelligence, and with early interventions, dyslexic students can successfully learn to read and write.

The term 'struggling readers' is sometimes used to describe individuals facing reading challenges. However, this term looks at the deficit of the learner, rather than their abilities. For some people, the term dyslexia means that language learning is problematic—dyslexia is about what learners cannot do and not what they can (Csizér et al., 2010). Although the more inclusive term is arguably 'those who need more support with reading', the terms 'dyslexia' and 'dyslexic learners' will be used in this thesis, as they are more commonly used in the literature. Dyslexia encompasses a range of reading difficulties, and it is essential to recognise that reading involves not just word recognition but also comprehension. Pang et al. (2003) note that early progress in reading depends on oral language development, with phonological and phonemic awareness closely associated with reading ability, and vocabulary being crucial to reading comprehension. For dyslexic learners, the reading process can be frustrating, often leading to missed learning opportunities. Thus, it is important to support these learners so they can access the wealth of information available in written texts.

Most of the CALL research is based on neurotypical adult English language learners (Ward, 2018). There is some focus on secondary school students (e.g., Macaro et al., 2012), but there is a limited focus on primary school learners (e.g., Ward, 2007). CALL research mainly focuses on L2 learners, but many CALL resources could also be helpful for L1 learners (e.g., dyslexic students). The term assistive technology in education is used to refer to the use of technology and tools to support learners. Assistive technology has been used to support dyslexic students in L1 reading and writing (Dawson et al., 2019). It is interesting to note that the first issue of Language Learning and Technology journal looked at language education and learning disabilities (LeLoup and Ponterio, 1997).

The pre-reader phase begins in infancy and will last until a child begins to actively learn to read. Researchers have reported on how technology can support pre-readers (Verwimp et al., 2023) and the importance of enjoyment for pre-readers (Vanden Bempt et al., 2022). Motivating and reaching all at-risk pre-readers to engage in reading programmes can be achieved through the use of digital serious games (Verwimp et al., 2023). Vanden Bempt et al. (2021) note that technology can make a difference for pre-readers at cognitive risk for dyslexia (Dutch and Finnish).

Beltrán et al. (2013) provide a good overview of inclusive language education and digital technologies and Crombie (2013) reports on inclusive practice and technology in the dyslexia context. There are differing findings in relation to reading on paper versus digital reading with Støle et al. (2020) reporting that some students are better at reading on paper, while Schneps et al. (2013) note that e-readers can be helpful for those with dyslexia due to the short lines of text in e-readers. In general, there are indications of the benefit of digital technology in the dyslexia context, but more research is required (Bautista et al., 2023).

Barzillai and Thomson (2018) advocate the need for a more nuanced understanding regarding the challenges and potential of digital environments and highlights the uniqueness of each child's digital reading experience. *A is for App* [2] provides information on reading fluency apps for struggling readers in primary school. Liu et al. (2024) give an overview of the use of digital technologies to develop young children's language and literacy skills. Messer and Nash (2018) note the

[2] `https://www.aisforapp.eu`

effectiveness of a computer-assisted reading intervention to address reading delays.

During the field research experiments of this project, learners with dyslexia were encountered, leading to further considerations in this area. As the Cipher game demonstrates, immersion in stories can help bolster language skills, however children with dyslexia often avoid text-based tasks due to accumulated experiences of excessive effort and/or failure. This avoidance can then lead to a vicious cycle of reduced academic achievement. In this project, the Cipher game was adapted to make it more accessible and appropriate for learners with text-based language difficulties, such as dyslexia. The most basic adaptations involve reducing the amount of text on each screen and carefully monitoring the readability of the text (both in the target story, as well as in the scene-setting and instructional support). The inclusion of specific magic spells in the game can be used as a tool to help dyslexic learners detect and correct spelling patterns commonly reported in dyslexic learners of English (Pedler, 2001), such as difficulties with more complex vowel spellings (e.g., split vowel digraphs a-e, i-e), and confusion of consonants with similar articulatory and visual features (e.g., b, d, p). In this research, text that is not part of the active learning segments is augmented with Text-to-Speech (see Section 5.6), so that understanding text instructions is not a barrier to gameplay.

In summary, while more research is needed to fully understand the potential of digital technologies in supporting dyslexic learners, existing studies indicate that these tools, when thoughtfully applied, can play a significant role in supporting reading and language development in dyslexic learners.

2.2 Culturally Informed Approaches for Indigenous Languages

2.2.1 Indigenous Language Revitalisation in a Digital Age

According to Walsh (2005), indigenous languages are broadly defined as those that are 'native' to particular regions. For example, Irish is considered indigenous to

Ireland, and Hawaiian to Hawaii, whereas English, despite being spoken in both regions, is not classified as indigenous. The outlook for many indigenous languages worldwide is increasingly concerning, prompting a growing body of research dedicated to the issues of language endangerment and revitalisation (Walsh, 2005). Previous studies on indigenous language revitalisation highlight the important role of digital technology, which offers the ability to record, preserve, analyse, manipulate, and transmit languages in various ways, aiding their survival (Galla, 2018). Digital technology has been applied to the field of indigenous language revitalisation in various forms such as social media, mobile apps and VR (Galla, 2018; Outakoski et al., 2018). Galla (2016) conducted a 2009 survey of at least 47 indigenous languages and the findings suggest that digital technology positively impacts indigenous language learning and teaching (Galla, 2016). Digital technology can provide powerful tools when it comes to connecting native speakers and learners virtually regardless of time, space and geography, which provides learners with excellent opportunities to access and engage with the languages and the community (Galla, 2018). In addition, studies show that indigenous youth are active users of digital technology, which can help them reconnect to their heritage and the languages. With active engagement and interaction with digital technology, indigenous youth also gain an increasing amount of language exposure consciously and unconsciously. Furthermore, emerging technologies like VR allow young learners to have immersive experiences that reconnect them to the land where they were born and where the languages reside, helping them reconnect to the spirit of the language. Furthermore, with the help of technology, learners are less afraid of making mistakes, which reduces the risk of embarrassment and ridicule (Galla, 2018). This enables them to feel more confident and comfortable using their own language. However, digital technology may not appeal to some groups of people (e.g., elders or older generations) in the community but “the future of indigenous language lies with the youth and future generation”, as Galla (2016) pointed out.

Digital technology can also be used for language documentation and material development with more efficiency, lower cost and more linguistic and cultural authenticity (e.g., image, audio, video) (Outakoski et al., 2018). According to Wemigwans (2016), digital ancestral knowledge is essential for preserving indigenous knowledge and supporting education. In addition, digitised indigenous knowledge may attract people beyond their own, which means people (e.g., language activists, educators) from other parts of the world can also contribute to the languages. For example, this research project benefited from the digitalisation of archived indigenous language materials (project Dúchas [3]), which allowed for the repurposing of these materials for DGBLL. More details can be found in Section 7.1.

In order for indigenous languages to thrive in the digital age, these languages must be used actively in all areas of life (Outakoski et al., 2018). This cannot be done without digital technology, as technology is linked to all aspects of our daily life and this link will grow even stronger in the future. Most of these indigenous languages are under-resourced so the development of digital technology for these languages needs to stand on the shoulders of giants in terms of both technology and languages. The Hawaiian language, for instance, has gained support from tech giants like Microsoft and Apple by adapting language technologies from language giants such as English. As a result, it is now supported on most major digital platforms (Galla, 2018). This has allowed the language to gain broader exposure in the digital world, creating more opportunities for both local and global engagement. In the case of Irish, the Irish government acknowledges the importance of technology for the language's future (Ní Chasaide et al., 2022) and emphasises the need for greater support from leading technology companies.

2.2.2 Reconnecting to the Spirit of Language: A Culturally Informed Approach in Indigenous Contexts

Languages across the globe are disappearing at an alarming rate, as noted by UNESCO (2022a). This phenomenon is partly due to a declining number of

[3] `https://www.duchas.ie`

speakers and a growing reluctance among younger generations, particularly in indigenous communities, to learn or pass on their ancestral languages. For instance, the disconnect between the Cree language and its speakers has been well documented. nêhiyawêwin (Cree language) is one of the most widely spoken indigenous languages in Canada. However, it experienced a significant decline due to colonisation and other historical disruptions that caused the disconnection between the nêhiyawak (Cree people) and the language. Research by Napier and Whiskeyjack (2021) on the Cree language underscores the importance of 'reconnecting to the spirit of the language' as a vital step towards language revitalisation. They propose a model that involves acknowledging historical harms, promoting healing, and reconnecting with cultural roots. This model suggests that the essence of a language is intertwined with the land and the ancestral laws of its people, and reclaiming this connection is crucial for its survival (Napier and Whiskeyjack, 2021). Although this theory is specific to the Cree language, it offers valuable insights that may be applicable to other indigenous languages facing similar challenges.

Similarly, the Irish language needs a reconnection to its spirit. Despite its rich cultural heritage, the language has faced centuries of suppression. As a member of the Celtic branch of Indo-European languages, Irish has been marginalised, particularly during periods when English was seen as the language of economic and social advancement. However, towards the end of the 19th century, scholars began to take an interest in ancient Irish legends and mythology, which led to renewed pride and interest in the Irish language (Gregory, 1904; Hyde, 1890; Ó Coileáin, 1988). Today, Irish remains a crucial part of Ireland's cultural heritage. Although approximately 1.87 million people claim to speak Irish, its daily use outside educational settings is limited (CSO, 2022). There is an urgent need for language learning support and creative ways to increase learners' contact with Irish on a regular basis (Dalton, 2016).

It is important to note that while 'reconnect to the spirit of the language' is the original concept used in Napier and Whiskeyjack (2021)'s study, this research expands upon the concept of reconnection. It not only includes re-establishing a connection but also forming a first-time connection. This is relevant for learners in Irish educational settings, where diverse cultural backgrounds in classrooms mean that for many, engaging with the culturally relevant content for the first time is a path toward cultural connection.

Drawing inspiration from the Cree language reconnection efforts, this research integrates the philosophy of 'reconnecting to the spirit of the language' into the Irish context through the digital game: Cipher. This approach uses Irish folklore and mythology to create an engaging learning experience. It aims to foster a deeper connection between learners and the Irish language, moving beyond the perception of Irish as merely a school subject to a vibrant part of cultural heritage. While the level of connection may vary and enthusiasm for the language might differ among individuals, many Irish people recognise that their language is unique and a significant part of their cultural identity. Given the complex social and cultural context of the language in Ireland, providing learners with an opportunity to reconnect with cultural roots can be a helpful approach.

Applying Napier and Whiskeyjack (2021)'s theory of 'reconnecting to the spirit of the language' is intended to enhance learner engagement and motivation in the Irish context—a model that could be replicated in other LCTLs. This approach not only can support language learning but also contributes to the broader goal of cultural preservation and in indigenous contexts.

2.3 Advanced Technology for Bridging Cultural Approaches and CALL in LCTLs

This section bridges the discussions from Sections 2.1 and 2.2 by focusing on the exploration of technologies that connect CALL with culturally informed approaches, specifically in the context of LCTLs. Technology has been mentioned throughout the previous two sections, establishing its clear role in bridging cultural approaches and CALL for LCTLs. Section 2.3 will examine specific technologies and their role in connecting cultural approaches with CALL in LCTLs.

2.3.1 Games

The term 'game' has been subject to diverse interpretations. Crawford (1984) described games as structured formal systems that present a subjective representation of a segment of reality. Similarly, Salen and Zimmerman (2004) identified games as artificially constructed environments designed to enable one or more players to participate. They outlined four key elements of games: objects, attributes, internal relationships, and an environment.

Adams (2014) characterised games as a form of play that takes place in a simulated environment, where participants strive to achieve goals under specific rules. Dempsey et al. (2002) described games as activities that include one or more players participating in competitive scenarios. Juul (2011) further refined this perspective by defining games as systems governed by rules, which generate outcomes valued differently by players.

Game mechanics, as described by Sicart (2008), are the methods employed by agents within a game to facilitate meaningful interactions with its state. These mechanics establish the connections between game elements and players, organising actions that promote engagement and accomplish game goals.

Rojas-Salazar (2022) synthesised various perspectives, identifying seven common characteristics shared across game definitions, as summarised in Table 2.3.

Games can take the form of physical activities (e.g., board games), digital experiences (e.g., video games), or a combination of both (e.g., phygital games (Torres, 2022)). Video games are operated on computers, including devices such as PCs, mobile phones, tablets, gaming consoles, and VR headsets (Adams, 2014).

Commercial off-the-shelf games are designed for entertainment (Rojas-Salazar, 2022). In contrast, serious games are created with purposes beyond

Characteristic	**Description**
System	Games are formal systems comprising interconnected components.
Rules	Games operate under rules.
Fantasy	Games feature fantasy elements, such as fictional worlds or abstract narratives.
Interaction	Games enable interaction among players and game elements, promoting engagement with the system and other participants.
Goals	Games involve one or more goals that players strive to achieve.
Challenges	Games present challenges that need to be overcome to reach these goals.
Outcomes	Games have outcomes.

Table 2.3: Characteristics of Games (Rojas-Salazar, 2022)

entertainment (Becker, 2017), serving educational, meaningful, or purposeful functions. These games often address specific objectives and audiences (Petridis and Traczykowski, 2021). For instance, serious games can be categorised into exergames, advergames, or educational games based on their aims (Dörner et al., 2016). Digital Educational Games (DEGs), a subset of serious games, utilise the captivating and immersive features of video games to achieve specific educational goals (De Freitas and Oliver, 2006).

This study focuses on DEGs, exploring their potential to create meaningful learning experiences through structured and learner-centred gameplay.

2.3.2 Digital Educational Games

For many years, it has been known that games can contribute to learning (Dixon et al., 2022; Facer, 2003). Digital Educational Games (DEGs) involve the use of computer game characteristics for educational purposes with a focus on learner engagement. They can be motivational for students and encourage self-efficacy (Acquah and Katz, 2020; Dixon et al., 2022). Motivation is especially important in any language learning context (Dörnyei and Ushioda, 2021) and self-efficacy or autonomy is important in learning contexts as it promotes student engagement and learning (Linnenbrink and Pintrich, 2003). Also referred to as Digital Game-Based Learning (DGBL) in some contexts, DEGs have been utilised for a variety of purposes, such as language learning (Dixon et al., 2022), promoting cultural heritage (Ćosović and Brkić, 2019), and supporting children with ADHD (Bul et al., 2015). Well-designed games encourage players to engage in complex and critical thinking (Gee, 2003) and promote learning through experiential changes over time (Schunk, 2012).

In recent years, there has been a growing body of research on Digital Game-Based Language Learning (DGBLL), where language learning is a desirable byproduct of gameplay. Sørensen and Meyer (2007) observe a shift in language learning technologies from rote memorisation techniques, focused on drills, grammatical structures, and translation tests, towards more context-based methods emphasising task-based, project-based and content-based learning. Games can serve as a catalyst for this transformation. Game progression depends on players' performance of skills, which are developed through their actions within the game context, rather than simply memorising information or providing correct answers in a traditional educational setting (Dunkel, 1991; Sørensen and Meyer, 2007). While conventional education emphasises tests and competence, game-based activities prioritise performance within the game (Gee, 2005). For instance, individuals may be more inclined to read game-related texts, such as in-game dialogue, walk-throughs, or supplementary materials, in order to improve their performance or advance in the game, compared to reading linear texts assigned in a traditional academic setting. This repeated interaction with game content can enhance comprehension and retention (Smith, 1987; Turley, 2018).

Moreover, DEGs offer an advantage in facilitating access to minoritised languages. Commercial games typically support only a limited number of languages, primarily those with a large number of speakers, such as English and Spanish. In contrast, DEGs and gamified language learning apps, such as Duolingo, offer a wider array of language options, including many minoritised languages. According to the 2021

Duolingo Language Report, the platform supports over 40 different languages, and this number continues to grow (Blanco, 2021). Thus, DEGs have the potential to support the learning and teaching of minoritised languages.

2.3.2.1 Digital Game-Based Language Learning

Digital Game-Based Language Learning (DGBLL) merges the realms of gaming and language education, utilising digital games as a medium to enhance language acquisition (Chowdhury et al., 2024). This approach takes advantage of the engaging and interactive nature of games to create learning environments that can motivate learners and improve their language skills (Janebi Enayat and Haghighatpasand, 2019). The potential of DGBLL is rooted in its ability to provide meaningful and contextualised language practice in a fun way, offering a dynamic alternative to traditional language learning methods (Chowdhury et al., 2024). Research suggests that games can motivate readers (Martens, 2014; Ronimus et al., 2014), encourage writing, and can also be applied to instruction courses in reading and writing (Karadag, 2015). Studies have shown that digital games can provide rich, contextualised language input that enhances vocabulary skills (Chowdhury et al., 2024).

An increasing number of studies have analysed the impact of digital games on L2 developments and these studies have led to meta-analysis studies. Findings from these studies have reached the conclusion that digital games have positive effects on L2 learning, particularly on L2 vocabulary acquisition (Chen et al., 2018; Dixon et al., 2022; Tsai and Tsai, 2018). A meta-analysis (Dixon et al., 2022) of DGBLL studies revealed medium to large effect sizes for vocabulary acquisition, underscoring its effectiveness compared to non-gaming instructional methods. Dixon et al. (2022) suggests that DGBLL works better for games designed for entertainment than games designed for educational purposes and that the latter has been overlooked by the CALL community. This is primarily because DEGs often struggle to captivate players, given their overt educational objectives and the industry's lack of commercial interest (Reinhardt, 2019). Moreover, DEGs are often overshadowed by games designed for entertainment when it comes to engaging elements (e.g., storylines and graphics) and authentic language interaction (e.g., spoken and written input) (Dixon et al., 2022). However, it is worth noting that games designed for entertainment typically do not offer language options for minoritised languages due to low commercial interest. This mirrors the situation previously discussed regarding commercial games, which limits access to DGBLL opportunities for potential learners of these languages. Therefore, digital games specifically designed for minoritised languages are valuable for language learning in this context.

Language acquisition is highlighted as a key benefit of DGBLL (Dixon et al., 2022). However, the diversity in game mechanics poses challenges in generalising outcomes across different game types (Chen et al., 2018; Tsai and Tsai, 2018). Despite these challenges, the growing popularity and accessibility of digital games, coupled with their application across various languages, underscore the growing importance of DGBLL in modern language education (Dixon et al., 2022).

In this project, DGBLL is seen as the bridge between CALL for LCTLs and culturally informed approaches, with specific technologies addressing the technical gaps (see Sections 2.3.4 and 2.3.5). One innovation of this research is the combination of DGBLL and the philosophy of 'reconnecting to the spirit of the language'. Cipher, a DGBLL application for Irish, integrates game elements infused with folklore and culture alongside educational content to enhance the learning experience for Irish language students. Based on current understanding, Cipher Faoi Gheasa [4] is the first DGBLL game of its kind for the Irish language.

The current body of research on games for the Irish language is very limited, with only a few available studies as mentioned in Section 2.1.5. Previous research integrating games and cultural approaches into Irish CALL has utilised Virtual World Language Learning (VWLL) in combination with Task-Based Language Learning (TBLL) approaches (Collins et al., 2019; Dalton and Devitt, 2016).

[4] *Faoi Gheasa* translates to *Under a Spell* in Irish. The Irish version of Cipher, formally named Cipher Faoi Gheasa, is referred to simply as Cipher throughout this thesis for brevity.

According to Prabhu (1987), TBLL suggests that effective language learning occurs when learners engage in meaningful tasks, rather than merely learning about language structures (Oxford, 2006). Breen (1987) describes these tasks as outcome-oriented instructional plans that facilitate language learning, ranging from simple to complex, depending on the focus (e.g., forms or meaning). Franciosi (2011) notes that both DGBLL and TBLL are rooted in problem-solving and influenced by constructivism. However, DGBLL typically features clear, quantifiable goals that are easy for players to understand, while TBLL tasks often have more abstract goals requiring instructor explanation. Additionally, games can adapt in real time to match the learner's skill level, whereas TBLL often offers a one-size-fits-all approach and does not adapt to individual learner needs in real-time. Franciosi (2011) suggests that language learning tasks could benefit from incorporating game design principles, such as clearer goals and balanced difficulty. Lai and Li (2011) also highlights that technology (e.g.,digital games) can potentially enhance task-based language development. These elements are reflected in the project Cipher.

Virtual World Language Learning (VWLL) refers to the integration of language learning into immersive virtual environments where learners interact with their surroundings, encouraging language acquisition (Dalton and Devitt, 2016). VWLL and DGBLL, while related, differ primarily in their goal orientation. For example, VWLL environments in studies such as Dalton and Devitt (2016) and Collins et al. (2019) for Irish language learning are open-ended, emphasising social interaction and constructivist learning without specific objectives. As a result, in their studies, students' actions are driven by goal-oriented TBLL. This makes VWLL and TBLL an effective combination. In contrast, DGBLL integrates clear goals and narratives within the game design, making objectives intrinsic to the gameplay (Cornillie et al., 2012). In their research, Dalton and Devitt (2016) pointed out children prefer more game-like environments with clear tasks and goals, making DGBLL a suitable option for schoolchildren.

In summary, DGBLL represents a dynamic and engaging approach to language learning, particularly well-suited for younger learners, those seeking a more immersive and interactive educational experience and a potential pathway for enhancing L2 acquisition.

2.3.2.2 Game Adaptivity and the Zone of Proximal Development

As previously noted, one of the advantages of DGBLL is its ability to adapt in real-time to the player's skill level. Adaptive educational games, by design, blend the immersive appeal of gaming with personalised learning experiences, creating environments where learners are both motivated and engaged. Research by Peirce et al. (2008) highlights the intrinsic motivation these games provide, emphasising their ability to adapt without sacrificing engagement. The innovation in non-invasively adapting games strikes a balance between delivering educational benefits and preserving the game's immersive appeal for players.

According to Acquah and Katz (2020)'s systematic review of empirical evidence on the effectiveness of digital games for second language (L2) learning, the main game features that influence outcomes are ease of use, challenge (i.e., being in the Zone of Proximal Development), rewards and feedback, control or autonomy, goal orientation, and interactivity. This section focuses on the challenge feature, particularly how the Zone of Proximal Development (ZPD) can be leveraged to enhance both engagement and adaptivity.

Zone of Proximal Development (ZPD) serves as a metaphor for the potential of human cognitive growth. See the diagram in Figure 2.1. Introduced by Vygotsky (1978), the ZPD represents the gap between what a learner can accomplish independently and what they can achieve with support from more knowledgeable individuals, such as teachers, parents, or peers, as well as through the use of cultural artefacts.

ZPD has been widely applied in various language learning contexts. For instance, the language learning app Duolingo incorporates this principle by tailoring its exercises to align with each learner's ZPD (Freeman et al., 2023), ensuring that

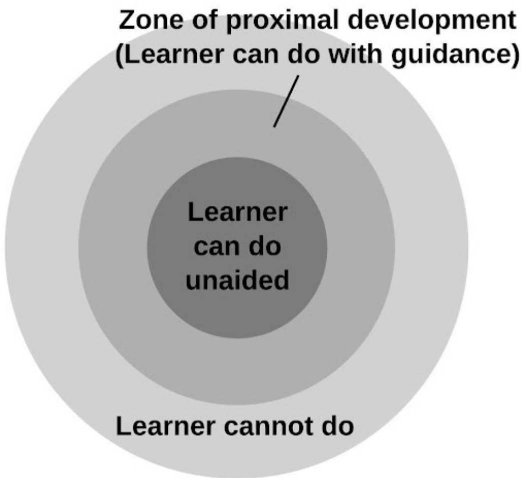


Figure 2.1: Zone of proximal development illustration, sourced from Wikimedia Commons.

tasks are challenging enough to promote effective learning. Duolingo's AI algorithm, known as 'birdbrain', personalised language learning exercises for each user, helping them operate at the edge of their abilities, or within their ZPD. Specifically, birdbrain predicts the likelihood of a learner's success on each exercise, such as estimating an 81% chance of success for one learner on a particular task, while recognising that a more challenging exercise might have only a 45% success rate for the same learner, indicating that the exercise is not yet appropriate for their lessons. In contrast, this challenging exercise might be suitable for another learner with a higher predicted success rate, such as 79%, which may fall within their ZPD.

When aiming to achieve the ZPD, where learning occurs when the game is challenging but not overly so, it is crucial that educational content is adapted in a way that does not disrupt the gaming experience. This involves innovative approaches to personalising learning challenges and providing meta-cognitive support, ensuring that adaptations are non-invasive and augmentative rather than interruptive. Kickmeier-Rust et al. (2008) further highlight the role of micro-adaptivity in assessing competencies within games seamlessly, contributing to an improved learning and gaming experience compared to non-adaptive counterparts. Micro-adaptivity in the context of educational games involves a real-time, non-invasive method of evaluating a learners' knowledge and adapting the learning environment to their individual needs and abilities (Kickmeier-Rust et al., 2008).

Adaptive educational games offer a promising avenue for enhancing learning through personalised, engaging experiences. The careful integration of adaptivity, aimed at boosting motivation without compromising immersion, is essential. This approach not only enriches the educational potential of games but also preserves their intrinsic appeal as engaging and immersive entertainment mediums.

In the game Cipher, adaptivity is implemented by adjusting the difficulty of both the game's challenges (e.g., magical spells) and the accompanying text to match the player's skill level. This adaptivity is driven by the initial player sign-up data, such as age, school year, and type of school (i.e., whether English or Irish is the medium of instruction). Based on this information, the game selects the appropriate stories that align with the educational background of the players. As the game progresses, the difficulty of both the text and game's challenges dynamically adjusts according to the player's performance, a feature that will be detailed in Section 4.2. Furthermore, the game's use of text analysis and classification techniques for adjusting text difficulty, as detailed in Sections 5.3 and 5.4, ensures that the player's motivation and engagement are sustained through personalised experiences. This approach aligns with the principles outlined by Peirce et al. (2008) and Kickmeier-Rust et al. (2008), where non-invasive adaptations support both educational outcomes and the preservation of the game's intrinsic motivation.

2.3.3 DGBLL Evaluation

2.3.3.1 User Experience Study

Previous research and studies (Burrow and More, 2005; Gee, 2003; Schrier, 2006) suggest that Digital Education Games (DEGs) can facilitate learning in a more engaging and motivating way. However, evaluating the user experience of these systems can be very challenging, due to the fact that gaming and learning can be considered competing motives and can have a mutual influence on each other (Bul et al., 2015; Law and Sun, 2012). Isbister and Schaffer (2008) focus on the behaviour and feelings of users when they play the games. Bul et al. (2015) evaluates user satisfaction mainly on the basis of the gaming experience and the learning experience, while other researchers tend to focus only on how players feel when interacting with the system (Isbister and Schaffer, 2008). Elements such as usefulness and usability are not always considered important in experimental settings but this can affect engagement, as usability problems can cause a negative game experience (Law and Sun, 2012). Nacke et al. (2010) developed a three-layer evaluation framework comprising the quality of the product, the quality of human-product interaction, and the quality of this interaction within a given context. Law and Sun (2012) present a four-dimensional evaluation framework which focuses on the gaming experience, learning experience, adaptivity and usability. This four-dimensional model is used in the user evaluation study for this research.

2.3.3.2 Measuring Learning Effectiveness of DGBLL

Challenges

DGBLL represents a progressive and captivating method to facilitate L2 acquisition by harnessing the engaging nature of digital games. As highlighted earlier, the effectiveness of digital games on L2 development showed a medium to large positive effect, particularly in within-group designs (Dixon et al., 2022). Within-group designs involve measuring the performance of the same participants both before and after an intervention (e.g., playing a game), whereas between-group designs compare outcomes between separate groups, with one typically serving as a control group (Dixon et al., 2022). However, measuring the effectiveness of DGBLL presents several challenges, primarily due to the diversity of contexts, participants, and methodologies. One significant challenge is that most studies focus on commonly taught languages, such as English, with participants often being adults outside conventional learning environments. These studies often do not integrate the games into a structured classroom setting, leading to results that may not reflect the authentic learning experiences of schoolchildren (Miller and Hegelheimer, 2006; Noroozloo et al., 2015).

Another challenge is the context in which the learning takes place. Often, the game is not embedded within the students' regular curriculum, meaning participants are learning in an artificial environment that does not mimic the real-world classroom dynamics. This lack of integration can lead to an incomplete understanding of how DGBLL affects learning outcomes in a typical educational setting. As mentioned earlier, games designed solely for entertainment have been found to be more engaging and effective for language learning compared to those specifically developed for educational purposes (Dixon et al., 2022). This makes curriculum integration even more challenging. This is not just an issue for DGBLL but a general issue of games for educational settings (Jääskä and Aaltonen, 2022).

Furthermore, a significant issue arises with tests designed to measure learning gains, as many studies use pre-tests and post-tests to assess language acquisition in DGBLL (Dixon et al., 2022), and participants may learn from the tests themselves. When the same or similar tests are used for both pre-tests and post-tests, there is a risk that score improvements are partly due to test familiarity (i.e., participants improve test results due to repeated exposure to the same test materials, rather than the intervention) or practice effects rather than the intervention itself (Davies, 1999).

Moreover, the age and language proficiency of participants add another layer of complexity. Studies involving younger learners or those with lower language proficiency levels often require different methodological approaches to accurately measure the educational effectiveness of DGBLL. For instance, the use of immediate and delayed post-tests helps in distinguishing short-term recall from long-term retention, providing a clearer picture of the intervention's impact (Dabrowski et al., 2024; Janebi Enayat and Haghighatpasand, 2019).

Addressing these challenges requires a multifaceted approach that includes integrating DGBLL into authentic learning environments, using varied and contextually rich assessments, and ensuring a diverse participant pool to enhance the generalisability of the findings. In this research, we implemented strategies to address some of these challenges.

Mitigating Test Familiarity in DGBLL

As previously mentioned, test familiarity is a concerning issue when demonstrating learning gains in DGBLL. To address this, researchers have implemented various strategies to prevent learners from acquiring knowledge from the tests themselves in studies investigating the effectiveness of DGBLL for vocabulary acquisition. These strategies ensure that the observed improvements in language skills, such as vocabulary knowledge, are attributed to the intervention rather than test familiarity.

A common approach is to use pretests and posttests with the same items presented in different orders (Alfadil, 2020; Jia et al., 2024; Noroozloo et al., 2015). This method minimises the likelihood that participants will remember the order of answers from the pretest, thus reducing the practice effect.

Furthermore, contextualised testing involves embedding test words in meaningful sentences or providing cues to ensure that students understand the context and meaning of the words. Jia et al. (2024) designed receptive vocabulary tests with words embedded in sentences and productive vocabulary tests with cues and initial letters. This reduced the likelihood of memorising words without understanding their context and meaning. Janebi Enayat and Haghighatpasand (2019) also implemented contextualised sentences in their tests to ensure a deeper understanding of the vocabulary items being assessed. Including both experimental and control groups is one of the most common approaches. This allows researchers to distinguish the effects of the intervention from test familiarity (Alfadil, 2020; Chowdhury et al., 2024; Elaish et al., 2019; Janebi Enayat and Haghighatpasand, 2019; Noroozloo et al., 2015). This design allowed for a clear comparison of the vocabulary gains attributed to the intervention versus traditional learning methods.

Lastly, delayed posttests assess long-term retention, distinguishing between immediate recall and sustained learning. Dabrowski et al. (2024) conducted delayed posttests one week after treatment sessions to measure long-term retention of vocabulary. Janebi Enayat and Haghighatpasand (2019) included a second posttest to measure the long-term effect of the intervention, ensuring that observed gains were due to the learning intervention rather than test familiarity.

These methodological strategies collectively aim to mitigate the possibility of learners simply learning from repeated test exposure, ensuring that observed vocabulary gains are attributable to the educational intervention. In this research, it is acknowledged that learners may acquire knowledge from the tests themselves, and this possibility is accounted for in the data analysis. Inspired by Üstün-Yavuz (2024), two pre-tests were conducted for both the experimental and control groups. This double baseline model establishes a comprehensive baseline, ensuring that observed improvements in vocabulary acquisition are more likely attributable to the DGBLL intervention.

2.3.3.3 Double Baseline Model for Learning Effectiveness Evaluation

The double baseline model, as explained by Üstün-Yavuz (2024), is used in the field of language intervention research on supporting struggling readers, presents a novel approach to evaluating language learning effectiveness. This model involves establishing two baseline measurements before implementing an intervention, providing a clearer picture of the intervention's true impact by accounting for natural variations and potential pre-existing trends in the data.

In the context of DGBLL, this model can address some of the common challenges mentioned in previous sections. Traditional pretest-posttest designs often struggle with issues like test familiarity. By incorporating a second baseline, researchers can better distinguish between genuine learning gains from the intervention and those resulting from repeated exposure to test materials.

This method allowed for the identification of subtle changes in learning trajectories that might be overlooked with a single pretest. Applying this model to DGBLL can enhance the accuracy of effectiveness evaluations, particularly for Less Commonly Taught Languages (LCTLs) like Irish, where conventional vocabulary tests might not exist.

In this research, adopting the double baseline model involves conducting two pre-tests to establish a comprehensive baseline for both the control and experimental groups. This approach helps mitigate the influence of external factors and test familiarity, ensuring that any observed improvements in language proficiency are more likely to be attributed to the DGBLL intervention.

As mentioned previously, research on games for Irish language learning remains sparse, with existing studies overlooking learning gains, underscoring the need for further investigation in this area. More comprehensive analyses of DGBLL for LCTLs, such as Irish, are needed, particularly when integrated into authentic learning contexts.

2.3.4 Artificial Intelligence

A comprehensive examination of AI is beyond the scope of this study. This section instead offers a concise overview of AI, including a brief explanation of its fundamentals, the 'false dawns' in its development, and its application in CALL. It also provides a short summary of Natural Language Processing (NLP), AI image generation and Text-to-Speech (TTS) systems and their roles in CALL.

There is no singular definition of AI, but it can be defined as the use of computer technology to simulate human intelligence and problem-solving capabilities (Wang, 2019). The general public has gained most of its perceptions from films and books, which can sometimes give the idea that AI robots can 'think' or 'feel'. However, this is not true with the current state of AI development and it may then become a philosophical question if it is even possible for a non-human to 'think' and 'feel'.

Since the public release of ChatGPT [5] in November 2022, the general public has become more aware of the existence of Generative AI (GenAI) tools and their usage. Those not previously familiar with AI tools in general, and GenAI tools in particular were amazed at what they could do. In educational settings, particularly in Higher

[5] `https://chatgpt.com`

Education, there were initial concerns in relation to academic integrity, as there were fears that students would use GenAI tools to do their assignments for them (Sullivan et al., 2023). Although this continues to be a concern, there are potential benefits in integrating AI into teaching and learning (Grassini, 2023).

While ChatGPT brought GenAI into the public spotlight, it is neither the first nor the only tool of its kind. GenAI encompasses a class of algorithms designed to generate outputs like text, images, and audio (Feuerriegel et al., 2024), using computational frameworks such as Generative Adversarial Networks (Goodfellow et al., 2014) and transformer architectures (Vaswani, 2017). Pre-trained on extensive datasets, these models are capable of producing outputs similar to human-created content, as seen in applications like ChatGPT. GenAI has found widespread application across diverse domains, ranging from creative industries and education to technical problem-solving and research (Brynjolfsson et al., 2023; Feuerriegel et al., 2024). However, the rapid proliferation of GenAI has also introduced challenges, including ethics-related issues of originality, potential misuse, and the propagation of biases originating from the training data. Addressing these concerns requires robust ethical frameworks to ensure responsible development and deployment (Al-kfairy et al., 2024).

While GenAI represents a revolutionary approach, it is part of the broader continuum of AI methodologies that also include more traditional approaches. AI, as a field, has a long history that predates modern computing and extends to conceptualisations in non-computational dating back even earlier (Muthukrishnan et al., 2020). Over the years, elements of AI have had different names (e.g., expert systems, intelligent systems) and subfields of AI have their own specific names. When computing technology became available in the 1940s and 1950s, there was great hope that AI could be harnessed to carry out difficult tasks and there were some initial successes from the 1950s to 1970s (Haenlein and Kaplan, 2019). However, there were many difficulties including computing power and finance issues. In the 1980s, there was a brief flurry of activity in AI, but it is mainly since the late 1990s and early 2000s that AI has really become more common and used outside the lab environment. Tasks that could only be performed in specialised computer labs can now be performed by the general public on a daily basis. For example, many people use spelling and grammar checkers in word processors without realising that AI partly powers these tools. They interact with these tools seamlessly, without considering the underlying technology.

The evolution of AI can be categorised into distinct phases. The early phase, known as symbolic AI or 'Good Old-Fashioned AI,' relied on explicit rules and logic to simulate human reasoning processes (Haugeland, 1989). This rule-based approach, discussed by McCarthy et al. (1955), gained prominence in the mid-20th century but faced limitations when addressing real-world complexities. AI advanced into a new era with the development of machine learning, which introduced statistical and algorithmic methods capable of learning patterns from data (Mitchell and Mitchell, 1997). Traditional machine learning approaches, such as logistic regression, support vector machines, decision trees, and random forests, became widely applied across various domains (Shinde and Shah, 2018). However, these methods still required extensive feature engineering and domain-specific insights. The emergence of deep learning marked a transformative stage within machine learning. Deep learning utilises artificial neural networks to automatically extract features and learn from raw data through multiple layers of non-linear processing (LeCun et al., 2015). Unlike traditional machine learning methods that depend on feature engineering, deep learning systems streamline this process, enabling breakthroughs in tasks such as image recognition, speech processing, and natural language understanding (LeCun et al., 2015).

AI has been used in CALL for many years. The use of AI in CALL has often been referred to as Intelligent CALL (ICALL). It has been used with written learner language in spell checkers, grammar checkers including systems for automatic writing evaluation, and Intelligent Language Tutoring Systems (ILTSs) (Heift, 2017). It has also been used to enhance reading, listening and speaking (Woo and Choi, 2021). In recent years, AI-driven technologies such as NLP and TTS tools have been used in

CALL resources.

2.3.4.1 Natural Language Processing

Natural Language Processing (NLP) designed to interact with and process human language for various purposes, including speech recognition, natural language understanding, and natural language generation (Jurafsky and Martin, 2014). NLP encompasses a range of tools and technologies, for tasks such as tokenisation, morphological analysis, syntactic and semantic parsing, text classification, and text summarisation.

Historically, NLP relied on symbolic approaches, which use predefined rules and grammars to process language (Nadkarni et al., 2011). Examples include early syntactic parsers that employed 'context-free grammars' to process syntactic structures (Chomsky, 1956, 1959). While these rule-based methods were effective in constrained environments, they faced challenges when scaling to real-world language scenarios. For instance, the ambiguity and variability of language, such as polysemy (i.e., words with the same spellings but different meanings), often exceeded the capacity of these systems (Manning, 1999).

Pre-trained Language Models (PLMs) represent a significant advancement in NLP. PLMs are pre-trained on large-scale unlabelled corpora of text. These models can subsequently be fine-tuned with labelled data for specific downstream tasks or employed directly for zero-shot (without examples) and few-shot (with examples) tasks through prompting (Lyu, 2023). A notable example is Bidirectional Encoder Representations from Transformers (BERT), which uses deep neural network architectures to learn contextual representations of language (Devlin et al., 2019). BERT and its variants have demonstrated better performance than previous methods across diverse NLP tasks, such as sentiment analysis and question answering (Devlin et al., 2019; Lyu, 2023). The development of decoder-based architectures, such as the Generative Pre-trained Transformer (GPT), further extended the capabilities of PLMs (Radford, 2018). These models introduced autoregressive modelling, which facilitated generative capabilities.

Building on these advancements, the success of PLMs led to the development of Large Language Models (LLMs) like GPT-3 (Brown et al., 2020). As part of the GPT series, GPT-3 served as the foundational architecture for the development of ChatGPT. LLMs are characterised by their immense scale, comprising billions of parameters. LLMs excel at both zero-shot and few-shot learning, powered by extensive pre-training on vast and diverse datasets. This allows them to generalise across tasks without requiring additional task-specific training, making them ideal for tasks like machine translation and summarisation (Brown et al., 2020; Lyu, 2023).

Many language learners currently use NLP-embedded tools for writing (e.g., spelling and grammar checkers) (Ferris et al., 2013). NLP tools have the potential to enhance the development of CALL resources and also increase their effectiveness (Greene et al., 2004; Ward, 2017, 2019). However, there have been difficulties in using NLP in CALL over the years (Greene et al., 2004). One fundamental issue is the cross-disciplinary nature of the integration—it can be challenging for NLP researchers to work with learners and CALL researchers to work with NLP technologies that they may not fully understand. NLP researchers focus on the technical aspects of NLP, while pedagogy is the main focus of CALL researchers. Furthermore, NPL tools are not designed for language learning activities and it can be difficult to adapt them for language learning purposes (Antoniadis et al., 2013). Other challenges, such as CALL development difficulties (Godwin-Jones, 2013), integration (Heift, 2017), financial constraints and the difficulties in building a multidisciplinary team, are also persistent issues (Ward, 2015a). Moreover, the development of NLP resources is particularly challenging for lower-resourced languages, further complicating their application in CALL. Despite these challenges, NLP technologies can be used in games to improve DGBLL (Ward et al., 2022). For instance, NLP is useful in automating the process of text preparation in language games.

In the context of the Irish language, the small global number of learners often makes it not economically viable for companies to develop CALL resources, let alone games for the language. Reinhardt (2019) notes that the CALL community has generally viewed language learning games unfavourably, partly because of the game industry's limited investment in this area. However, as detailed in Section 2.1, there is a substantial need for additional language input sources, such as games, for Irish learners.

Although Irish is a low-resource language, there are NLP tools that have been particularly useful in this project, including the Irish Part-of-Speech (POS) tagger (Uí Dhonnchadha and Van Genabith, 2006), Gramadóir (Scannell, 2005) and gaBERT (Barry et al., 2021).

For example, the Irish POS tagger annotates a text with POS tags and lemmas. The Irish POS tagger uses a rule-based approach rather than a machine learning approach as there were no annotated corpora available for this first POS tagger for Irish. Rule-based approaches are particularly important for low-resource languages. The Irish POS tagger was used to supply the Cipher engine with POS-tagged texts, and it was also used in the initial classification of texts so that players would be shown a text appropriate for their level of Irish. Gramadóir is a spelling and grammar checking tool for Irish that incorporates rule-based POS taggers (Scannell, 2005, 2006). It takes in text in Irish and identifies any words that are either misspelt or grammatically incorrect. Gramadóir is used as part of the Cipher pipeline to spellcheck the manually standardised texts used in Cipher: Faoi Gheasa. gaBERT (Barry et al., 2021) is a BERT model specifically adapted for the Irish language, designed to process Irish texts. It has been used for text classification tasks in this research.

2.3.4.2 Text-to-Image Generation

Images have the power to help contextual written texts and can make CALL resources more visually appealing (Schroeder et al., 2011). AI image generation (or Text-to-Image Generation AI) is complex and requires input parameters or conditions (prompts) to generate an image based on what it has learnt based on previous images it has seen (training images). AI image generators can generate images of both real and imaginary subjects.

Text-to-Image Generation (TTIG) AI has become a powerful tool in game asset development. GenAI, particularly TTIG, has emerged as an innovative resource for game design and visual arts, enabling the generation of diverse visual content. TTIG models, such as DALL-E [6], Midjourney [7] , Stable Diffusion [8], and Imagen [9] , are self-supervised deep learning models trained on massive datasets. They can generate high-quality images based on multi-modal commands, including text descriptions and user-provided images. These models enable the manifestation of imaginative concepts, the fusion of unrelated objects, and variations of existing images (Ko et al., 2023). The game industry has embraced TTIG models (Vimpari et al., 2023), with the CEO of Unity, a leading game engine company, stating that GenAI will have a transformative impact on gaming (Koetsier, 2023).

Certain models have been trained on open source datasets and made available online for people to access freely (Ko et al., 2023). Moreover, models like Stable Diffusion are open-source but require a subscription for access. Vimpari et al. (2023) emphasise the empowering capabilities of TTIG models, enabling users to generate visually appealing content without requiring conventional artistic expertise, which can be financially out of reach for LCTLs with limited resources.

Some benefits of AI image generators include time-saving, cost efficiencies, the ability to customise images, scalability, consistency and accessibility (especially for those who lack design or artistic skills) (Vimpari et al., 2023). Therefore, TTIG models find applications across various visual art domains such as graphic design, UI design, webtoons, digital art, and new media art.

However, there are also issues with AI generators. They tend to generate predictable images, lack support for personalisation, and can restrict creativity

[6] `https://openai.com/index/dall-e-3/`
[7] `https://www.midjourney.com`
[8] `https://stability.ai/stablediffusion`
[9] `https://imagen.research.google/`

when solely relying on text prompts (Ko et al., 2023). There are ethical concerns surrounding the images used to train generators, such as potential copyright issues. Additionally, there are broader concerns about the impact on artists and designers. Other issues include the generation of inappropriate images that reinforce stereotypes, the spread of biased or harmful content, and the creation of deep fake images (Vimpari et al., 2023).

For example, AI generated images have become very realistic in recent years. There is a phenomenon associated with images or virtual humans called the uncanny valley (Seyama and Nagayama, 2007). This is where images or virtual humans appear real but there is something 'different' about them and this can cause an uncomfortable sensation in the viewer. Recent AI tools (e.g., Dall-E) can generate images that are very realistic, with less of the uncanny valley effect. However, there are still residues of this in the images, but sometimes viewers have to look hard to find 'strange' elements. One area where AI-generated images often struggle is the rendering of human hands, which can sometimes appear 'unnatural'. The prompts provided to AI image generators are key to successful generation of images. It can be difficult for AI generators to generate similar images for a sequence of pictures. While AI image generators have been around since the 1970s, it is only in recent years that they have become available, usable and (financially) accessible to the general public.

Despite these limitations and concerns, TTIG has firmly arrived in the game industry and visual art field and is expected to impact the creative process from early ideation to the final product's assets (Vimpari et al., 2023).

TTIG was utilised in DGBLL to enhance the game experience and address the lack of resources in the Irish language. While generative AI for text, such as ChatGPT, still struggles with low-resource languages, generative AI for images can be explored as an alternative solution to the resource gap in the context of LCTLs. In this project, English is used as the prompt language for generation of images specifically related to Irish culture and folklore. Initially, the inclusion of imagery in the Cipher game seemed impossible given our limited budget and the lack of pre-existing suitable images. However, the advent of AI image generation means that it is possible to generate customised images at a reasonable cost. However, the process of generating suitable images still requires substantial time and effort. For example, there were issues with generating suitable images of females for the storylines as there seemed to be just a limited number of (often inappropriate) female stereotypes available. Generating images with multiple story elements was also problematic. As noted by Elasri et al. (2022), there is a significant semantic gap between the text domain and the image domain. However, with perseverance and more varied and detailed prompts, it is possible to generate suitable imagery. AI systems such as Midjourney, transform image generation for lower-resourced languages where traditional methods of generating images would not be commercially viable. More details regarding the implementation process can be found in Section 5.5.

2.3.4.3 Text-to-Speech

Text-to-Speech (TTS) Synthesis is a transformative technology that converts written text into spoken language. TTS tools are not only beneficial for blind and visually impaired individuals but also for those with reading difficulties, including dyslexia. The development of TTS systems has progressed steadily, evolving from early mechanised or rule-based synthetic speech to advanced end-to-end models that now deliver a quality comparable to human speech (Tan et al., 2024; Wang et al., 2017).

Initially, TTS technology was clunky and available only for a limited number of languages, particularly English. However, it has since improved significantly and is now accessible in many languages (Pratap et al., 2024). These tools can be integrated into devices, accessed via the web, and used in specialised apps to support students with reading challenges, complementing their existing school resources. In language learning, TTS can be especially helpful for learners unfamiliar with the L2 writing system, aiding in pronunciation (Fouz-González, 2015).

TTS technology has proven valuable in language learning (Woo and Choi, 2021).

It holds substantial potential for applications in CALL, functioning as a reading aid, pronunciation model, and conversational partner (Handley, 2009). Research by Huang and Liao (2015) highlights its positive impact on vocabulary enhancement, reading comprehension, and fluency. TTS is particularly beneficial for learners with dyslexia, as it triggers phonological awareness and reduces reading fatigue. Handley (2005) observed that TTS tools were already suitable for use in CALL, and TTS technologies have since seen considerable improvement. TTS can enhance reading comprehension, word recognition, and decoding skills (Keelor et al., 2020). It also promotes a more positive attitude towards reading and increases reading time (Harvey et al., 2013). Additionally, TTS can help students with disabilities stay on par with their peers across all subjects, improving self-esteem, motivation, and self-confidence. Diprossimo et al. (2023) report the benefits of vocabulary scaffolds for learners.

Despite these advantages, TTS in CALL is under-utilised, particularly in primary and secondary education (Raffoul and Jaber, 2023), underscoring the need for further integration of TTS into diverse educational contexts. The integration of TTS tools into reading support programmes can be challenging. For instance, Fälth and Selenius (2024) note that while teachers are generally supportive of technology use, they often lack awareness of available tools as well as the confidence and competence to use them effectively with their students.

2.3.5 Virtual Reality

Virtual Reality (VR) is widely defined as a computer-generated, immersive experience that replicates or simulates real-life environments (Kardong-Edgren et al., 2019). This technology has rapidly evolved and is now being utilised across various fields (e.g., gaming, education, health care, psychology) for its unique ability to create realistic environments. In the context of education, VR has emerged as a promising tool for enhancing language learning (Lin and Lan, 2015; Vázquez et al., 2018) and fostering cultural awareness (Cheng et al., 2017).

VR-based educational games offer considerable advantages over traditional 2D games by providing enhanced immersion, interactivity, and personalised learning experiences, making them more effective educational tools. VR transforms passive learning into active exploration, motivating students, particularly in science education, to become problem-solvers and experimenters (Lin and Cheng, 2024). VR enhances visualisation and comprehension of complex concepts, surpassing the capabilities of traditional 2D methods (Falah et al., 2021). However, studies have shown that VR experiences can sometimes cause motion sickness, detracting from the learning experience (Cheng et al., 2017; Wu and Tu, 2023). VR content development and implementation can be complex and time-consuming, requiring substantial resources and expertise. Despite these challenges, VR has the potential to revolutionise education by providing immersive, interactive, and personalised learning experiences, making it a highly promising tool (Lin and Lan, 2015).

In this VR implementation, both physical interaction (retrieving letters and rearranging them in 3D space) and cognitive engagement (vocabulary word puzzles) are provided. These activities, combined with immersive 3D visual imagery, help reinforce the words in the player's memory.

2.3.5.1 Virtual Reality for Language learning

According to Lin and Lan (2015), the number of VR studies on language learning has increased in recent years. However, it has also been reported that a large portion of VR concepts and features are still left unexplored and neglected in the field of CALL (Li et al., 2020; Schwienhorst, 2002). Two important features of VR are immersion and interaction, which makes VR beneficial to learners as well as being an interest of language educators (Lan, 2020). Sykes et al. (2008) divided VR into three categories in terms of its original design purposes, i.e., open social virtualities, massively multiplayer online games and synthetic immersive environments, all of which have the potential to benefit language learning. CALL researchers have made some effort to investigate the pedagogical perspectives of VR for language learning despite its original purposes for entertainment (Lin and Lan, 2015). In order to fulfil the purpose of language learning, it is believed that several aspects need to be taken into account when it comes to VR. This includes learners' linguistic knowledge and competence, and the process of acquiring the language (Lan, 2020). Regarding the methodological approaches, most VR studies on language learning are conducted through qualitative methodological approaches and about one third of VR studies applied both qualitative and quantitative approaches (Lin and Lan, 2015).

Applying VR to language learning has various benefits. First of all, research suggests that VR learning can increase cognitive engagement compared to traditional classroom instruction (Chen, 2016). This is because users can experience environments that are learner-centred and learner-controlled. Secondly, studies have shown that VR may lessen the stress associated with language learning, allowing students to practise specific skills (e.g., speaking and listening) in authentic contexts without feeling self-conscious or anxious (Lan, 2020; Tai, 2021). Thirdly, due to the fact that VR can imitate the real environment while putting learning resources to use in the virtual world, it makes learning materials more approachable to students. Fourthly, VR improves interaction and provides learners with a unique channel for interactivity (Ip et al., 2016; Lan, 2020). Fifthly, VR has been shown to have the ability to promote and facilitate language learners' autonomy, resulting in them becoming more autonomous language users who can choose, organise and evaluate learning resources on their own (Schwienhorst, 2002). Last but not least, VR enables the use of some cutting-edge technologies like NLP, which also have an impact on CALL (Schwienhorst, 2002; Ward, 2018).

The possible benefits of adopting VR for language acquisition are listed in Table 2.4. Overall, the concentration on CALL environments rather than isolated computer tools, as with many other CALL applications, is a huge advantage of VR (Schwienhorst, 2002). In addition, Lin and Lan (2015) saw a rise in the usage of VR for language learning in casual settings outside the classroom, making VR for CALL more widely available. Although there has been an increasing number

Benefit of VR for CALL	**Comment**
Increase cognitive engagement	Learning environments created by VR are learner-centred and learner-controlled.
Lessen the stress associated with language learning	VR enables students to practise particular skills in real-world settings without feeling self-conscious or frightened.
Makes learning materials more approachable to students	While learning resources in the virtual world, VR imitates the real world.
Improves learners' interaction	VR provides learners with a unique channel for interactivity.
Promote and facilitate language learners' autonomy	Language learners benefit from VR by becoming more autonomous users who can choose, organise, and assess their own learning materials.
Enables the use of cutting-edge technologies like NLP	To enhance CALL applications, VR and NLP can be integrated.

Table 2.4: VR's potential to boost language acquisition

of VR assets for learning various languages, most of them are focused on dominant languages (e.g., English). VR has great potential for the learning and teaching of LCTLs, despite these languages being severely underrepresented in the field of CALL.

2.3.5.2 Virtual Reality in Cultural Context

The use of digital technology in the preservation and revitalisation of indigenous languages has become increasingly popular (Galla, 2018). Research indicates that VR can aid in revitalisation by providing immersive and interactive environments (Minestrelli et al., 2024). Additionally, VR games have been shown to enhance cultural awareness and heritage through immersive experiences (Shih, 2015). VR is particularly effective in engaging the young, who are crucial for the continuity of language. It not only bridges the geographical and temporal gaps between native speakers and learners in a virtual world but also boosts learners' confidence by providing a safe space for practice without fear of judgement (Lan, 2020). Moreover, VR allows learners to immerse themselves in the landscapes and cultural contexts of the languages, fostering a deeper connection and understanding (Outakoski et al., 2018).

By immersing learners in the rich folklore and mythology of their languages, VR can create a connection to the language's roots, thereby not only teaching the language but also rekindling or initiating a cultural bond. This approach aligns with the growing recognition of the importance of culturally grounded education methods in the preservation and revitalisation of indigenous languages globally (UNESCO, 2024).

2.3.5.3 Cultural Approaches in Virtual Reality for Irish Language Learning

This research employs DGBLL and cultural approaches within a VR game.

VR environments can simulate specific contexts, making them ideal for language learning (Collins et al., 2019). Interaction is not just a helpful condition but an essential force for learning (Saville Troike, 2006), a notion that underpins VR's effectiveness in language education (Dalton and Devitt, 2016). Collins et al. (2019) highlight that VR's immersive and interactive nature supports situated learning by allowing learners to engage with the language in a realistic and interactive environment. These studies collectively illustrate that VR can provide rich, interactive environments that are conducive to language learning. They demonstrate how VR can bridge the gap between theoretical principles and practical applications, offering a novel and effective approach to promoting the learning of the Irish language.

VR offers immersive experiences that can create meaningful contexts for language use, which is critical for languages like Irish that lack substantial real-world practice environments beyond educational settings. Situated learning (Lave, 1991) posits that learning occurs through social interactions within a community of practice. Collins et al. (2019) investigated the impact of VR on adult learners' situated identity in learning Irish. The findings indicated that the intervention reduces anxiety levels and fosters a sense of belonging among Irish learners by allowing them to interact with native-speaking avatars in a virtual community of practice. The study also highlighted the educational value of VR, demonstrating its potential to create a believable reality and positively influence learners' attitudes towards the Irish language community. Recent studies underscore the potential of VR in enhancing language acquisition through immersive and contextually rich environments (Lan, 2020; Lin and Lan, 2015) and the aim is to apply this in the context of Irish.

Unlike previous studies in the Irish context that emphasise the social interaction, this research focuses on the cultural and historical elements in language learning. The VR version of Cipher immerses players in Irish mythology and folklore, encouraging learners to reconnect with the cultural roots of the language within an indigenous context through gameplay.

Thus, in this research, emphasis has been placed on incorporating Irish folklore and mythology to enhance the game's cultural relevance and appeal. As mentioned previously, DGBLL has been shown to be an effective way of encouraging learner motivation and autonomy. Beyond DGBLL, VR offers powerful tools to enhance this connection due to its interactivity and immersiveness. Research indicates that VR can boost cultural awareness and learner engagement (Çakır, 2024; Lan, 2020). By leveraging VR's immersive capabilities, Cipher VR seeks to transform how learners engage with the Irish language, helping to renew interest in it through the concept of 'reconnecting to the spirit of the language'. Further details are provided in Section 7.2.

2.4 Research Questions

2.4.1 Framework Summary

Chapter 2 has discussed the conceptual framework for integrating CALL for LCTLs with culturally informed approaches, along with the exploration of various technologies that have the potential to bridge the gaps in this process. The discussion was segmented into three main areas:

- **CALL for LCTLs:** This section provided an overview of CALL, highlighting its importance and the challenges faced, particularly in the context of LCTLs such as Irish. Issues related to motivation and resource scarcity were identified, along with the need for creative adaptations of existing technologies to improve language learning experiences.

- **Culturally Informed Approaches for Indigenous Languages:** The relevance of cultural aspects in language learning, especially for indigenous languages, was explored. The role of digital technology in revitalising these languages and the importance of reconnecting learners with their cultural roots were emphasised.

- **Use of Advanced Technology in Bridging Cultural Approaches and CALL for LCTLs:** The discussion focused on specific technologies, including Digital Educational Games (DEGs), Artificial Intelligence (AI), and Virtual Reality (VR), which can effectively bridge the gap between culturally informed approaches and CALL for LCTLs. These technologies were examined for their ability to create more engaging, adaptive, and context-specific language learning environments.

2.4.2 Technology Mapping

The synthesis of CALL for LCTLs, informed by cultural approaches and enhanced by innovative technologies, supports the development of context-specific language learning frameworks. The following mapping illustrates how the technologies discussed in Section 2.3 can address the challenges and opportunities identified in Sections 2.1 and 2.2:

- **Digital Educational Games (DEGs):** Digital Game-Based Language Learning (DGBLL) serves as a powerful component of DEGs, particularly effective in enhancing motivation and engagement among learners of LCTLs. It achieves this through culturally relevant game narratives and adaptive learning experiences, aligning with the need for context-specific CALL resources, as identified in the Irish language case study.

- **Artificial Intelligence (AI):** AI technologies can strengthen DGBLL by offering tailored learning experiences through NLP and adaptive learning algorithms, particularly for LCTLs and learners with dyslexia. Additionally, TTIG can create culturally relevant visual content, and TTS systems provide pronunciation models, making the learning experience more immersive and accessible to learners of low-resource languages. Together, TTIG and TTS help compensate for the resource limitations often faced by LCTLs.

- **Virtual Reality (VR):** VR provides immersive experiences that connect learners with the cultural and mythological aspects of their languages, reinforcing the cultural connection essential for language learning, especially in the context of indigenous languages.

Additionally, although this research primarily focuses on LCTLs, these technologies present opportunities for learners with specific challenges, such as dyslexia. By integrating visual aids, auditory reinforcement, and game elements, these tools enhance accessibility and engagement, contributing to more inclusive language learning environments in CALL.

2.4.3 Research Questions

Based on the literature review and the research objectives (see Section 1.2), the following Research Questions (RQs) have been formulated:

RQ1: How can existing game resources designed for dominant languages be repurposed for low-resource languages within the context of CALL?

RQ2: How can Advanced technologies (i.e., AI and VR) be leveraged to enhance DGBLL for LCTLs?

- **RQ2.1: How can AI (i.e., NLP, TTIG, and TTS) be utilised to strengthen DGBLL resources for low-resource languages?**

- **RQ2.2: How can VR be used to enhance DGBLL resources and create CALL environments for low-resource languages?**

RQ3: How can language learning pedagogy be incorporated into DGBLL and evaluated to support LCTLs?

- **RQ3.1: How can language learning pedagogy be integrated into DGBLL to support LCTLs?**
- **RQ3.2: How can the effectiveness of language learning pedagogy in DGBLL be evaluated for LCTLs?**

RQ4: How can cultural approaches be integrated into CALL for indigenous languages?

- **RQ4.1: How can existing indigenous language resources be repurposed for DGBLL?**
- **RQ4.2: How can the theory of reconnecting to the spirit of the language be applied to indigenous language learning through DGBLL in VR?**

2.5 Conclusion

Addressing the identified gaps requires a strategic approach that includes leveraging existing technologies and resources, fostering interdisciplinary collaboration, and applying innovative adaptation techniques. The subsequent chapters will further elaborate on these solutions, demonstrating the potential of integrating technology and cultural elements to enhance CALL for LCTLs, with a specific focus on the Irish language as a case study. However, the proposed framework is designed to be language-independent and adaptable to other LCTLs with adjustments, ensuring broader relevance and impact.

Chapter 3

An Overview of Cipher: Learner-Centred Game Design

3.1 Introduction

This chapter explores the practical application of technology-driven approaches to language learning through the development and integration of Cipher—a Digital Educational Game (DEG) designed to address the unique challenges of learning Less Commonly Taught Languages (LCTLs), particularly Irish. Chapter 2 established the conceptual framework of Computer-Assisted Language Learning (CALL) for LCTLs, the specific challenges in the Irish context, and the role of cultural approaches and emerging technologies. Chapter 3 transitions to a comprehensive exploration of how Cipher applies these theoretical insights to practical use.

The Irish language, like many minoritised languages, faces distinct social and cultural challenges such as declining use, negative perceptions, and limited resources, both in and outside the classroom. Chapter 2 identified these barriers and emphasised the importance of cultural immersion and relevance in motivating learners. Cipher addresses these issues by grounding its narrative in Irish myths and folklore, allowing learners to connect with their culture through meaningful language engagement. The game's storyline, where players decode magical tales to restore disrupted stories, serves as both a linguistic and cultural bridge, offering learners a deeper connection to the language and its historical context.

Chapter 2 also underscored the potential of DEGs, Artificial Intelligence (AI), Virtual Reality (VR), and other technologies to enhance the learning experience for LCTLs. In response, Cipher integrates these tools to create a more immersive, adaptive, and engaging learning environment. AI-generated visual elements, for instance, provide learners with context-specific feedback, improving their comprehension and engagement. The incorporation of VR further extends the game's ability to offer learners a fully immersive experience, placing them within interactive, culturally rich environments that foster both language acquisition and cultural appreciation. The iterative co-creation process, driven by feedback from both learners and teachers, ensures that the game evolves to meet the needs of diverse users, particularly in low-resource educational contexts. Additional details are provided in Section 3.4.

Cipher embodies a practical application of CALL for LCTLs like Irish, addressing both pedagogical needs and cultural challenges through an innovative blend of cultural approaches and emerging technologies. This chapter traces the evolution of Cipher from a conceptual idea to a fully realised educational tool, demonstrating how its pedagogical principles, Design-Based Research methodology, along with technological enhancements create an inclusive, adaptive, and culturally resonant environment for language learners.

3.2 Pedagogical Integration

References: This section is based on my contribution to (Ward et al., 2023).

Developing CALL resources is a complex task that requires a multidisciplinary team (Ward, 2015b). Each team member brings a unique perspective such as the teacher focuses on pedagogy, the developer on technical implementation, the Natural Language Processing (NLP) expert on language processing, the game developer on gaming, and the CALL expert strives to maintain a balance between all of these elements (not all projects require every role). To create effective CALL resources, collaboration and co-creation among team members is crucial. This section explores the complexities of developing and evaluating CALL resources through the lens of a digital game-based CALL resource for Irish, undertaken by a team consisting of a teacher, a game developer, an NLP specialist, and a CALL researcher. It explores the challenges, opportunities, and the delicate balancing act required during development, to achieve a 'Goldilocks compromise' rather than 'Cruella de Vil chaos'.

CALL resource development can also be frustrating for individual team members. Each member is usually most focused on getting their part 'right', and having to make compromises with the other team members can sometimes require patience. The teacher wants to focus on pedagogy, the NLP specialist wants to focus on getting the NLP aspects right, the game designer wants to make sure that the game element is kept to the fore, and the CALL researcher aims to ensure that insights from CALL research underpin the development process.

This section investigates the pedagogical integration of Cipher. Current Irish language teaching is textbook-based and students have very limited access to digital resources (Harris et al., 2006; Martinez Sainz et al., 2023). To better align the Cipher game with the school curriculum, the original team—comprising a digital game developer, an NLP researcher, and a CALL researcher—was expanded with the addition of primary school teachers. The end goal for the team was the development of a game for learners of Irish that would be an attractive game, while at the same time being aligned with the school curriculum. The game texts are based on fairy tales and myths, and the challenge is to weave the desired pedagogical components into the narrative in an unobtrusive manner, with an emphasis on maintaining the game's ambiance. We wish to avoid a 'chocolate-covered broccoli' situation (Hopkins and Roberts, 2015), whereby it becomes a gamified language learning resource which duplicates the curriculum, rather than a CALL resource which complements the curriculum and enhances the learning experience. This section reports on the pedagogical integration process used to ensure better alignment with the school curriculum. It looks at whether a 'Goldilocks compromise' was reached or whether 'Cruella de Vil chaos' ensued, and offers suggestions for other CALL researchers considering adopting a similar approach.

3.2.1 Pedagogical Design Principles

Designing and developing a Digital Game-Based Language Learning (DGBLL) application is both exciting and challenging. It is exciting in that you get to design a new game and it can be a very creative process. However, there are many challenges. These include the difficulty in the development of the game from a technical perspective and the need to ensure that the game has the right blend of game and pedagogical components. If the game elements are strong, but the pedagogical elements are weak, there may be limited learning benefits for players. If the pedagogical elements are strong but the game elements are weak, there may be limited enjoyment for players and it could be just another case of chocolate covered broccoli. With this in mind, Cipher was designed with three principles for learning: a focus on pedagogy, alignment with curriculum and co-creation.

3.2.2 A Focus on Pedagogy

When designing a DGBLL resource, it can be tempting to focus on the game elements, which can be more exciting than the pedagogical elements. However, research from the field of CALL consistently highlights the need to focus on pedagogy when designing CALL resources, including DGBLL. Technology should be used to enhance the language learning experience, and not just 'technology for the sake of technology'. It should take into consideration what language skill is being targeted (e.g., reading, writing, speaking or listening), the language ability of the learner (e.g., from absolute beginners to advanced learners - see CEFR [1] and the specific pedagogical focus of the resource.

The game uses storytelling to engage learners, immersing them in tasks that involve deciphering 'magic stones' and 'enchanted scrolls', which correspond to ciphered words and texts respectively. These elements serve as both metaphorical

[1]`https://www.cambridgeenglish.org/exams-and-tests/cefr/`

and in-game representations of language learning challenges, including the vocabulary acquisition task (see Figure 3.1) and the reading comprehension task (see Figure 3.3). The game also features a writing task (see Figure 3.2), where players must rearrange the scrambled words into a sentence. This task not only reinforces vocabulary learning but also enhance the understanding of word usage and sentence structure. If players fails to rearrange the words correctly, they will lose the 'attempt' to revive the game character and continue playing. Screenshots of learning elements in Cipher can be found in Figures 3.1 to 3.3. Through a series of engaging challenges and levels, players decode words and texts, with vocabulary embedded in context. AI-generated images are integrated for contextual illustration of vocabulary, reading and sentence tasks, making them easier to understand.

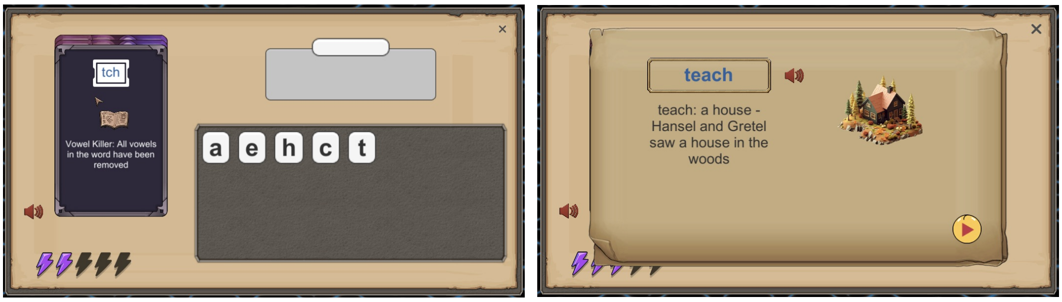


Figure 3.1: Vocabulary task in Cipher.

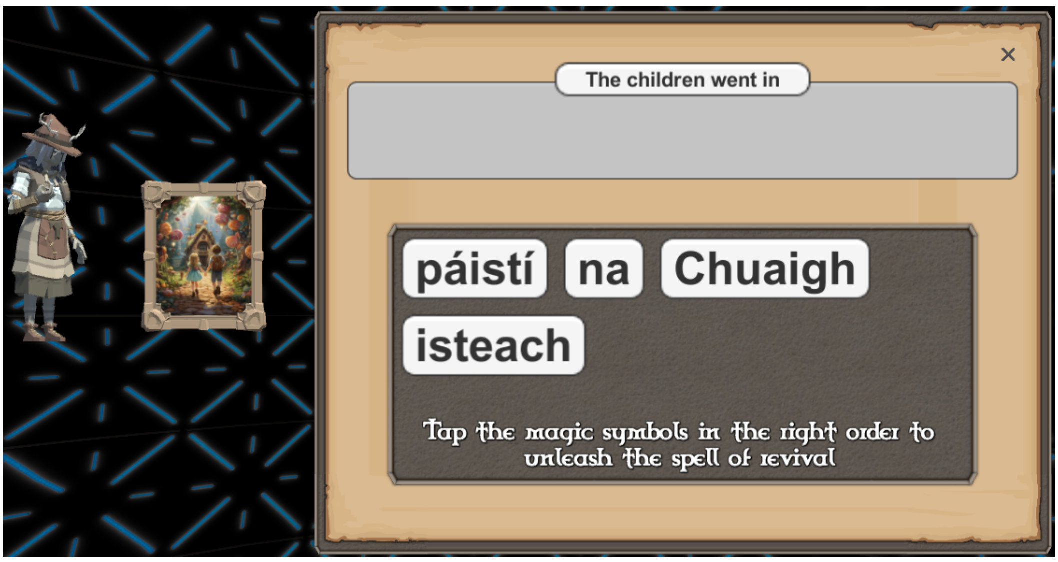


Figure 3.2: Writing task in Cipher.

Figure 3.3: Reading task in Cipher.

3.2.3 Curriculum Alignment

Curriculum alignment implies that the content covered is aligned with and supports the curriculum being taught. A key element in the successful use of CALL resources, including in the primary school context is curriculum alignment (Ward, 2007). This is particularly the case for Irish, where there is limited time for teaching and learning Irish and limited integration of CALL in the primary school classroom in the context of Ireland(Inspectorate, 2022; Ward, 2007). If CALL and DGBLL resources are to be used, they should be relevant and related to what the teaching is doing in the traditional classroom context.

In the context of the Cipher game, this involved looking at the primary school curriculum for Irish and reviewing the topics listed. It meant looking at school text books and discussing with teachers about topics and themes that were relevant to them and their students. It involved looking at specific themes and determining the appropriate blend of story-words and words that were being covered in class. For example, the story of Hansel and Gretel includes many references to food. This was a natural place to check that relevant vocabulary words were used in the story.

However, there was a need for a careful balance between having many relevant vocabulary words, while still maintaining the flow of the story (and not making it a pure vocabulary list/game).

In the 1999 curriculum (Government of Ireland, 1999), the teaching of Irish was structured around 10 themes: mé féin (myself), sa bhaile (in the town/at home), caitheamh aimsire (hobbies), an scoil (school), siopadóireacht (shopping), an teilifís (television), bia (food), éadaí (clothes), ocáidí speisialta (special occasions), and an aimsir (the weather). In terms of curriculum alignment through gamification, each story focuses on a curriculum-aligned theme (e.g., food) and is represented as a 'magic book' in the game (e.g., The Book of Butterflies for Hansel and Gretel, The Book of Salmon for 'The Salmon of Knowledge', see Figure 3.4 to the left). Each story is divided into pages, which are gamified as chapters, with each chapter serving as a game level (see Figure 3.4 to the right). Each level includes vocabulary, reading and writing tasks (see the examples in Figures 3.1 to 3.3), as previously mentioned, and these tasks are based on the content on each page. This approach allows curriculum content to be seamlessly transformed into engaging game material.

Figure 3.4: The Book of Butterfly (left) and its chapters (right).

3.2.4 Co-Creation Process

Co-creation implies the collaborative creation of something between different parties. In education, particularly at the tertiary or higher level, it refers to co-creation between educators and students within a student partnership model (Bovill, 2020). As discussed previously, in the field of CALL, there are two primary types of potential end-users: educators/teachers and learners. Teachers know what they want to teach but may not know how to develop the necessary tools. Due to the multidisciplinary nature of CALL, its development often involves collaboration with other parties. Developers, for example, know how to develop a resource but may not be familiar with the pedagogical requirements. In a co-creation approach, it is acknowledged that no one person possesses all the knowledge needed to develop the desired system; however, together, they contribute their expertise to enhance the development of CALL resources, emphasising learner needs and the deployment context (Ward, 2015a).

Co-creation involves working collaboratively with various stakeholders throughout the design process. Participants typically bring different perspectives and insights, helping to ensure a more holistic approach. This co-creation approach aligns with learner-centred design. When developing CALL resources, it is important to have a multidisciplinary team. The team should adopt a co-creation approach, where each member is valued for their individual contributions and perspectives. CALL is a multidisciplinary enterprise. No one person has all the knowledge required to develop a CALL resource, but with a co-creation perspective, where mutual respect is paramount and a shared vision reigns, there is no doubt that the final product will add up to more than the sum of its parts (Ward et al., 2023).

Cipher was developed for English and then adapted and modified for Irish, with a particular focus on primary school learners. The first Irish version of Cipher was relatively successful and students were able to use it in their own classroom. However, there was a desire to make sure that the content was pedagogically focused and aligned with the school curriculum, as previous research indicates that this is important for the uptake of CALL resources in the school context (Ward, 2007). The Cipher team consisted of a game developer interested in learning motivation and cultural heritage, an NLP and Irish language expert, a primary school teacher and a

CALL researcher with an interest in resources for LCTLs. The game developer did not speak Irish and had not attended school in Ireland. The other team members had no game development expertise. The Irish language expert was not familiar with Irish pedagogy while the teacher was not familiar with CALL resources for Irish. However, all members of the team wanted to develop a useful and usable CALL resource for Irish by adapting and aligning Cipher with the Irish primary school curriculum.

The development of the learning materials involved four steps. Firstly, the game developer worked closely with the NLP and language specialist and CALL researcher to develop the initial version of each of the stories to be used in the Cipher game. The texts were chosen with the target language learners, primary school children aged 8-12, in mind. Secondly, the teacher reviewed the texts and suggested vocabulary words that could be added to the story, so that it would align with what was being taught in the classroom. Thirdly, there were discussions between the team members to strike the right balance between curriculum alignment and maintaining the game ambiance. In step 4, the final texts were agreed upon by the team and added to the Cipher game.

Figure 3.5 shows part of an initial version of the Hansel and Gretel story in the game. As the story deals with food, the teacher suggested that more food words could be added to the story. While the addition of some words makes sense, not all the words were added as this would change the focus of Cipher from a game to a vocabulary learning task. It would distort the story and dilute the game aspect of the CALL resource. Figure 3.6 shows part of the amended story in the game with the addition of some of the suggested words.

Collaboration was a key approach in the evaluation of Cipher. No one person has all the expertise and insights required to evaluate the game and its evaluation relied on contributions from teachers, learners, and the core Cipher team. The lead teacher's perspective ensured that there was curriculum alignment in Cipher and suggested the thematic approach of the Irish curriculum would be a useful approach

Translation:

"..., said the witch.

We are very hungry, said the children.

Look, I have sweets, chocolate, jam, cakes, and apples in the house, said the witch.

The children went into the house.

They saw a lot of foods. Suddenly the witch grabbed Hansel and put him in a cage ..."

Figure 3.5: Initial version of the Hansel and Gretel story in the game along with translation.

Translation:

"The witch came out.

Are you hungry? said the witch.

We are very hungry, said the children.

Look, I have sweets, chocolate, jam, cakes, crisps, and apples in the house, said the witch.

The children went into the house.

They saw a lot of foods - popcorn, pancakes ..."

Figure 3.6: Amended version of the Hansel and Gretel story in the game along with translation.

for Cipher, particularly in terms of future scalability. Students were also involved in the design process. Cipher has gone through several development iterations (see Section 3.4) and each version has added improvements based on feedback from the student as players. For example, the difficulty level was too high at the beginning, and this has been adjusted. A support mechanism (i.e., 'power-ups') was added for students who needed additional support, along with audio components.

The Cipher game was tested in primary school classrooms in Ireland. Cipher was installed on tablets and each student could play the game individually. Although there were issues with Wi-Fi access in one of the classrooms, the students enjoyed the game and the teachers reported that it was good for their students.

The co-creation aspect of the development was interesting and challenging. The teacher was experienced in her classroom and was familiar with teaching Irish in an English-medium primary school. She knew the curriculum and the level of students' knowledge of the language. The game developer stayed focused on the game element, while being guided by the other team members in terms of Irish language content. The Irish language expert tended to overestimate the Irish language ability of the English-medium primary school students, whereas the CALL researcher focused on ensuring the game functioned effectively, was appropriately tailored to the students' level, and supported their learning outcomes.

One clear example of the co-creation process in action was to do with the development of the content of the stories. The teacher was keen on ensuring that there were a good number of vocabulary words in each story. The game developer was concerned that this would detract from the game element. The NLP and Irish speaker was more concerned with maintaining the narrative aspect of the story from a linguistic perspective. At each step of the development process, there were collegial discussions between each of the team members with each person outlining their point of view. Each member recognised that the other members had a different perspective and that it was important to take these into consideration and that compromise was necessary.

From the inception of the collaborative undertaking, it became evident that every team member would make distinct contributions to the CALL development process. The game designer's understanding of game dynamics and commitment to preserving the game's atmosphere was instrumental in shaping the project. The teacher had expertise in the school curriculum, and understood the limited time dedicated to Irish language instruction within the school timetable, and the essentiality of providing relevant resources to students. The Irish language specialist was instrumental in maintaining a consistent standard of Irish throughout the project's progression. The CALL researcher recognised that certain compromises would be necessary to achieve the intended outcome. Despite not precisely achieving the 'Goldilocks zone', a harmonious collaborative effort prevailed, steering clear of the disorderly tendencies and 'Cruella de Vil chaos'.

3.3 Design-Based Research

Wang and Hannafin (2005) characterise Design-Based Research (DBR) as a systematic yet flexible methodology intended to enhance educational practices through iterative cycles of analysis, design, development, and implementation. This approach is grounded in collaborative efforts between researchers and practitioners within real-world contexts to derive contextually relevant design principles and theoretical insights (Wang and Hannafin, 2005). This iterative and flexible nature ensures solutions are empirically validated and practically applicable (McKenney and Reeves, 2018; Wang and Hannafin, 2005)

The origins of DBR can be dated back to the early 1990s through the pioneering work of Brown (1992) and Collins (1992), who introduced 'design experiments'. Their approach underscored the need to address questions that laboratory-based experiments could not adequately resolve, emphasising the importance of ecological and situational contexts (Barab and Squire, 2016). Over time, DBR has evolved into a flexible methodology for testing existing theories and generating new ones (Nic Réamoinn, 2024).

DBR draws inspiration from engineering design cycles (Dalton, 2016). For instance, software engineering approaches such as Agile (Cohen et al., 2004) follow a process of identifying problems, designing and prototyping solutions, testing, and refining them based on feedback, as shown in Figure 3.7.

Reeves (2006) highlights that DBR's iterative approach is integral to addressing complex educational challenges while simultaneously advancing theoretical understanding. As depicted in Figure 3.8, DBR process comprises iterative cycles of collaborative analysis, solution development, testing, and reflection (Amiel and Reeves, 2008). Each phase builds on the previous one, enabling researchers to address practical challenges while continuously improving interventions in dynamic, real-time contexts (O'Reilly, 2024).

One of DBR's strengths is its ability to bridge the gap between theory and

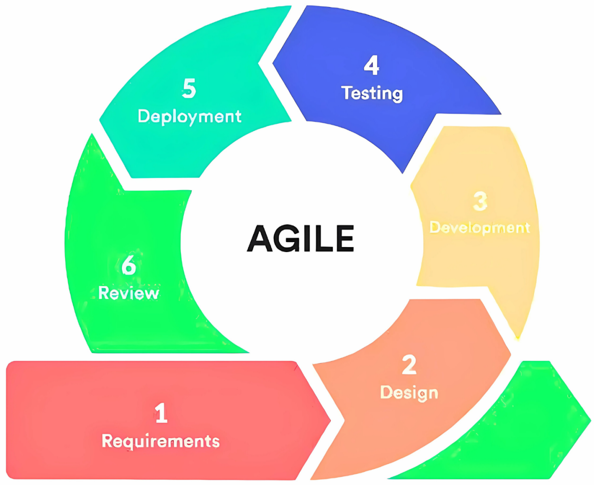


Figure 3.7: The Agile design process in software engineering (Okeke, 2021).

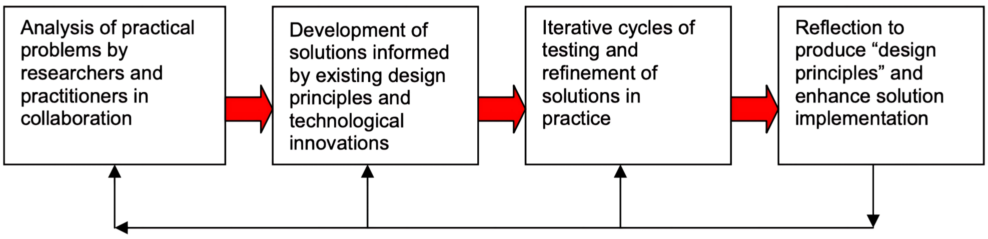


Figure 3.8: The DBR process: Refinement of problems, solutions, methods, and design principles (Amiel and Reeves, 2008).

practice. Practitioners are engaged as co-creators, contributing their expertise to ensure that solutions are both empirically grounded and practically relevant (Anderson and Shattuck, 2012). By combining scientific investigation with systematic development, DBR generates actionable insights that advance both educational theory and practice (Wang and Hannafin, 2005).

DBR operates within a pragmatic and ecological paradigm, emphasising the need to understand education not only as it is but also as it could or should be (Bakker, 2018; O'Reilly, 2024). This perspective supports researchers in exploring innovative practices and evaluating their effectiveness in naturalistic classroom settings and refining them based on empirical evidence (Brown, 1992; Reeves and McKenney, 2013).

DBR's iterative and collaborative nature makes it suitable for educational research involving technological interventions. Its multi-perspective approach facilitates the design and evaluation of tools that address specific educational problems (Dalton, 2016).

Table 3.1 summarises the core characteristics of DBR based on the research by Wang and Hannafin (2005):

Characteristic	**Description**
Pragmatic Focus	Advances both theoretical understanding and practical applications.
Grounded Effort	Driven by and rooted in relevant research, conducted in authentic, real-world settings.
Interactive, Iterative, and Flexible Process	Engages designers in iterative cycles of analysis, design, implementation, and refinement.
Integrative Design	Combines mixed research methods for comprehensive analysis and rigorous application.
Contextual Sensitivity	Documents solutions and processes for applicability across different settings.

Table 3.1: DBR Characteristics (Wang and Hannafin, 2005)

DBR offers a robust methodological framework for tackling complex educational challenges by integrating theory, design and practice in authentic settings. Its flexibility, iterative process and collaborative nature make it a valuable approach for developing and refining innovative educational solutions.

DBR was selected as the design approach for this study due to its robust capacity to bridge theoretical frameworks with practical applications in educational settings. The objectives of this research require an adaptable and iterative process to address the dynamic needs of learners and educators in Less Commonly Taught Languages (LCTLs) such as Irish. DBR's emphasis on an iterative and collaborative process facilitates the integration of multiple perspectives and stakeholder inputs, creating a feedback loop that informs and refines each cycle of design (Easterday et al., 2014). This approach aligns with the study's objectives, which involve testing and optimising the pedagogical intervention, Cipher, in classroom settings with both learners and teachers. Moreover, the flexible nature of DBR supports the integration of emerging technologies and accommodates the resolution of challenges and incorporation of new insights in real time. This ensures that the pedagogical intervention remains relevant and effective.

Figure 3.9 illustrates the iterative cycles of Cipher. Details of each stage of co-creation, implementation, testing and reflection, are elaborated in Section 3.4.

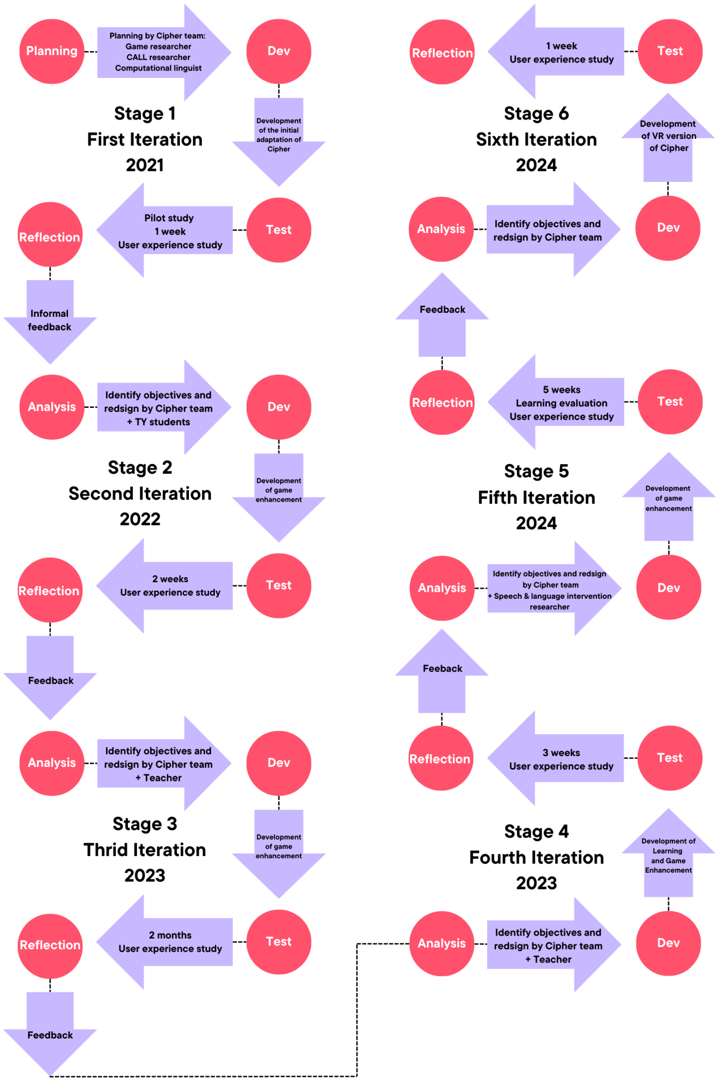


Figure 3.9: Diagram illustrating iterative cycles of Cipher.

3.4 Iterative Cycles of Game Design

Reference: This section is mainly based on (Xu et al., 2024c).

As shown in Figure 3.9, the game design for Cipher has undergone iterative cycles, incorporating feedback, learner needs and advancements in technology. The evolution of Cipher can be categorised into several stages, each aimed at enhancing language learning, gaming experience, inclusivity, and cultural approaches integration. Figure 3.10 provides an overview of the key features introduced at each stage of Cipher's development.

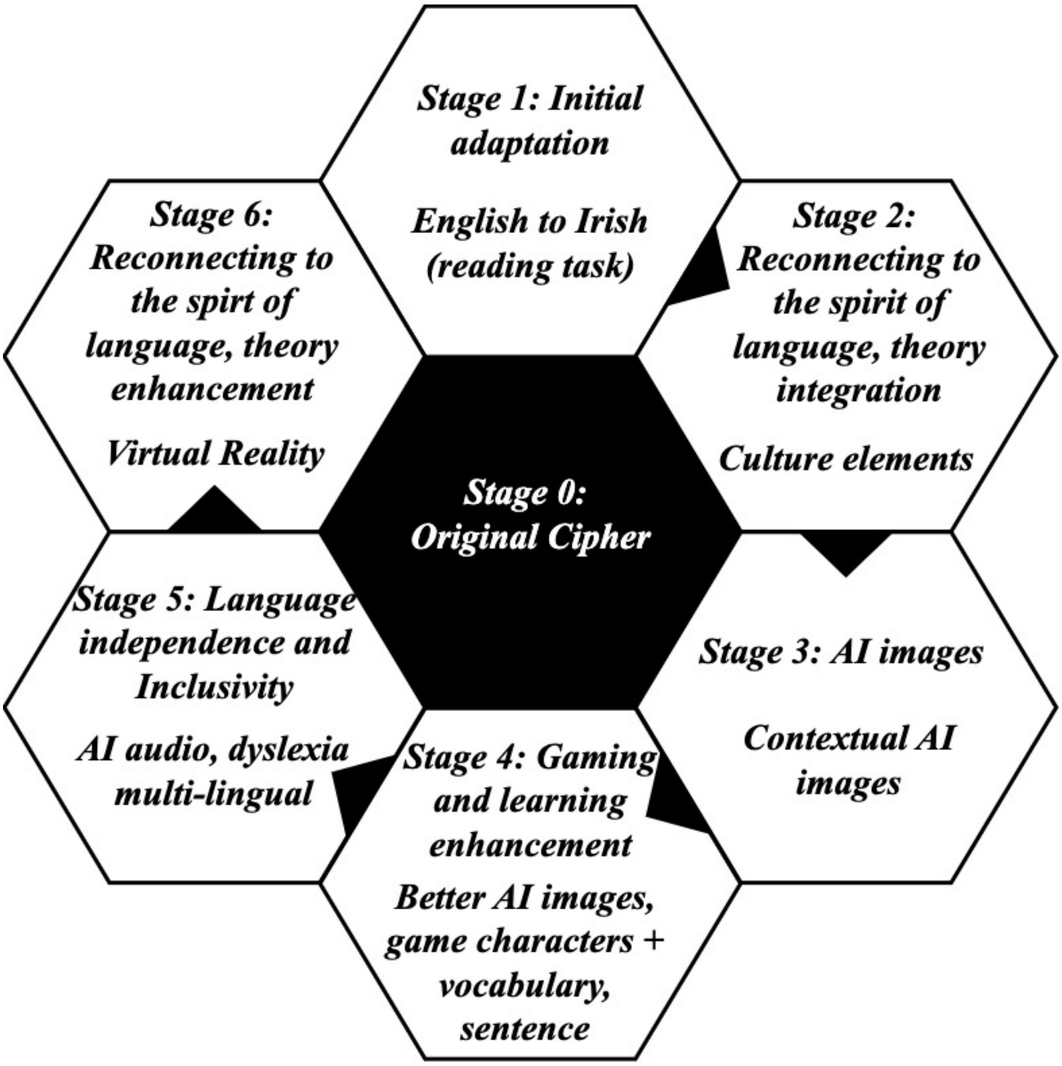


Figure 3.10: Diagram illustrating the evolution of Cipher.

3.4.1 Stage 0: Original Cipher

The original Cipher game (Xu and Chamberlain, 2020) was developed as part of the researcher's Master's research, with the primary goal of gamifying the task of text error identification. Text error detection is critical for various applications, including spell checkers, grammar tools, and Optical Character Recognition (OCR). However, traditional correction algorithms often struggle with complex or subtle errors, making it necessary to employ human expertise for better results (Gaur et al., 2016). This approach, however, is time-consuming and costly.

To address this, Cipher was designed as a 'game with a purpose' (Von Ahn, 2006), transforming text error identification into an engaging gamified experience. The game targets university students, particularly those with English as a second language, at B1 to C2 Common European Framework of Reference (CEFR [2]) proficiency levels. These students not only engage in a fun activity but also contribute valuable data by annotating texts and identifying errors. The text used in the game is sourced from the Phrase Detectives Corpus 1.0 [3].

Game Mechanics and Ciphers

Cipher operates by encoding texts with cryptographic 'ciphers'. These ciphers are patterns that modify the text according to specific rules, creating a challenge for players. For example, one cipher might remove all vowels from the text, while another could double the initial consonant of each word. The player's task is to decipher the encoded text, identify the errors, and understand the ciphers applied.

In addition to ciphers, real errors, such as misspellings sourced from Kaggle's English Common Error List, were integrated into the text to function as distractors (Xu and Chamberlain, 2020). These errors make the gameplay more complex by requiring players to identify both cipher-based transformations and real linguistic mistakes. Figure 3.11 is a screenshot of the original Cipher.

[2] https://www.cambridgeenglish.org/exams-and-tests/cefr/
[3] Available at http://anawiki.essex.ac.uk

Figure 3.11: A screenshot of the reading task in Cipher at stage 0.

Data Collection and Analysis

As players progress through the game, they earn points for correctly identifying errors and deciphering ciphers. Each identified error, whether known or unknown, is annotated, allowing researchers to collect valuable data for further analysis. For example, if multiple players click on a word that is not identified as a known system error (cipher error or inserted real error), insights can be drawn about whether this word is a genuine error in the original text. This data not only contributes to improving error detection algorithms but also provides insights into common text errors that players find challenging to detect.

Language Learning Potential

The positive feedback from initial testing confirmed that players found the game enjoyable and were able to identify errors with ease (Xu and Chamberlain, 2020). The potential of Cipher as a language learning tool emerged from these early tests, as players also reported improvements in their language skills while playing. This laid the foundation for future adaptations of the game, particularly its application in language education.

3.4.2 Stage 1: Initial Adaptation and Proof of Concept

3.4.2.1 Stage 1 Co-Creation and Implementation

The objectives for Stage 1 were defined collaboratively by the Cipher team, which included a game researcher, a CALL researcher, and a computational linguist. The focus was on creating an initial adaptation of Cipher to align with the objectives of Irish language learning.

Following the success of the original Cipher game, the first major adaptation focused on repurposing it for Irish language learning. This stage marked a transition from a game that detected errors in English texts to a tool designed for language acquisition in Irish, specifically targeting young learners at A1 to B1 CEFR proficiency levels. The goal was to utilise the successful framework of Cipher and apply it to LCTLs such as Irish, which often lacks the technological and linguistic resources available for more widely spoken languages.

Adapting Cipher for Irish Language Learning

While the original Cipher game utilised the Phrase Detectives Corpus 1.0 to supply English text with common error annotations, the Irish version required a different approach due to the scarcity of equivalent resources in Irish. In this stage, texts used in the game were drawn from Irish textbooks and corpora that were appropriate for younger learners, introducing pedagogically relevant content. However, unlike the readily available error datasets for English, such as those from Kaggle's English Common Error Lists, there was no pre-existing, comprehensive error list for Irish. This necessitated the development of an artificial error list to simulate the types of mistakes common in Irish writing.

The artificial Irish error list was curated for the Irish version of Cipher and it was a short experimental list derived from children's copybooks. It was created by the team's Irish NLP expert because no such resource was readily available. It included common spelling errors and other mistakes that learners are likely to make. This not only helped encode the text for the game but also played a critical role in understanding which errors students struggled with the most, providing valuable insights into common challenges faced by Irish language learners.

Game Mechanics and New Features

In this adaptation, the core mechanics of Cipher—where players decipher encoded text and identify errors—were retained. However, adjustments were made to suit the different linguistic characteristics of Irish. As in the original version, players were presented with text altered by a series of ciphers. These ciphers modified words according to specific rules, such as removing vowels or altering consonants. Players were tasked with identifying both the genuine linguistic errors and the ciphers at work.

An enhancement in this stage was the introduction of an error-noticing feature. This feature allowed players to directly compare their identified errors with the correct forms, providing a learning aspect. This feedback mechanism made the game a more effective tool for language learning by allowing learners to not only identify mistakes but also see the correct language structures. Figure 3.12 displays a screenshot of Cipher in Stage 1.

Figure 3.12: A screenshot of the reading task in Cipher at Stage 1.

3.4.2.2 Stage 1 Evaluation and Reflection

The focus in this stage was on adapting Cipher for Irish language learning, introducing both language-independent and Irish-specific ciphers to engage learners.

A one-week pilot study was conducted, consisting of a single 30-minute session and involved approximately 20 participants in an Irish-medium primary school for girls in Dublin. Due to COVID-19 restrictions, researchers were unable to access the venue. Instead, Android ACER tablets provided by Dublin City University (specifications not available) were sent to the school for the participants to use. Feedback was collected informally through the class teacher.

Nonetheless, the available feedback indicated that while the game was generally well-received, learners initially found it challenging to start. Students reported difficulty in understanding the rules and navigating the game mechanics. Once familiar with the game's structure, however, they found it more enjoyable. Another challenge noted by the students was distinguishing between real-world errors (distractors) and cipher-based alterations. This complexity, while intended to make the game engaging, proved too difficult for some learners at the lower CEFR levels. Consequently, it became clear that more explicit instructions and a clearer tutorial were necessary to improve the user experience.

Despite these challenges, the Irish adaptation of Cipher demonstrated that the core concept of the game was adaptable to different languages and learning environments. It also demonstrated that the game could be played in a classroom setting. The game's ability to make error identification fun while collecting valuable data about learner behaviour and challenges showed promise for its use as a DGBLL tool for language education. Further information regarding the initial adaptation in Stage 1 is provided in Chapter 4.

3.4.3 Stage 2: Game Enhancements and Cultural Approaches Incorporation

3.4.3.1 Stage 2 Co-Creation and Implementation

The Cipher team expanded collaboration to include Transition Year students. In Ireland, the Transition Year (TY) is an optional one-year program within the senior cycle of secondary education (NCCA, 2024). Schools encourage students to complete a few weeks of work experience during TY, offering an opportunity to gain practical skills and explore career interests. Co-design sessions were held to gather TY students' ideas for gameplay improvements.

Building on the initial adaptation of Cipher for Irish language learning, this stage introduced enhancements to both the gameplay and its underlying pedagogical framework. These changes were influenced by user feedback from the initial testing in the previously mentioned Irish-medium primary school, ideas from TY students and the integration of the theory of reconnecting to the spirit of language into the game's storyline and design.

The focus of this stage was to incorporate Irish mythology and cultural heritage into the game, aligning the learning content with a culturally relevant and engaging narrative. By doing so, the game aimed not only to support language acquisition but also to foster a connection between learners and the Irish language, reconnecting them to its rich cultural roots.

To address feedback from the initial adaptation in Stage 1, the decision was made to remove real-world error distractors from the game at this stage, focusing instead on cipher-generated errors that were more appropriate to the learners' language level. Players found the distractors too difficult to identify because they did not follow a clear pattern. This simplification made the game more accessible to younger students, reducing frustration and cognitive overload, and allowing them to focus more on the language learning tasks. Moreover, it addresses the common concern of familiarising learners with real-world errors.

Game Tutorial

Another critical piece of feedback from the previous stage was that the game was difficult to understand without proper instructions. To improve the user experience, a detailed tutorial animation was developed and integrated into the game, guiding players through the mechanics and rules step by step. Figure 3.13 displays two screenshots demonstrating how the tutorial works. The tutorial not only explained how ciphers work and how to identify and decipher them but also provided guidance on navigating the game interface, helping to create a smoother and more intuitive experience for learners.

Incorporating Cultural Approaches

One of the most important advancements in this stage was the incorporation of the theory of 'reconnecting to the spirit of language'. The game was redesigned to align with the theory of 'reconnecting to the spirit of language', adding a culturally rich narrative that framed the language learning experience within a magical, mythological world. The storyline introduced players to a world in which ancient mythological

Figure 3.13: Screenshots of game tutorial in Cipher

tales were placed under magical spells by an evil spirit, and it was the players' mission to restore these stories by deciphering the magical ciphers that had distorted them. Additionally, in this stage, the term 'cipher' was officially changed to 'magic spell' to better fit the game's theme.

The decision to base the game on Irish mythology and folklore, such as ancient tales from the Irish Schools Collection (Daly, 2010; Ó Cleircín et al., 2014), added cultural depth to the game. Firstly, it was hoped that this theme would have universal appeal to both young and old, as all generations can enjoy a good story (Garber-Barron and Si, 2013). Secondly, a mythological theme can be made culturally relevant for different language learning settings, making the stories more engaging for learners from diverse backgrounds. Thirdly, many folklore stories have the potential to raise learners' cultural awareness and reconnect to the spirit of language (Napier and Whiskeyjack, 2021).

While a culturally responsive approach to learning is often discussed in contexts of marginalisation (Sleeter, 2012), it is relevant in all learning environments, including those where learners are acquiring Irish. By weaving these mythological stories into the gameplay, the aim was to increase learners' engagement by offering them a more meaningful context for their language studies. Finally, stories and tales free from copyright restrictions were preferred, allowing the unrestricted incorporation of these culturally relevant narratives into the game.

Irish-Specific Ciphers

In addition to the storyline changes, new ciphers were introduced that were specific to the Irish language (see Figure 3.14). These included ciphers related to the linguistic features of Irish, such as accented vowels and word gender, which are important to the structure of the language. For example, ciphers like the ‘Accent Bomb’ (e.g., ‘bradán’ becomes ‘bradan’) or the ‘Vowel Sprout’ (e.g., ‘tine’ becomes ‘tíné’) modified vowels in ways that serve as metaphors for the challenges faced by learners of Irish. These challenges include the proper placement or omission of the fada (accent), a critical element in distinguishing meaning and pronunciation in the Irish language. Similarly, the ‘Solar Eclipse’ and ‘Lunar Eclipse’ ciphers related to the gender of nouns in Irish. Furthermore, the list of ciphers and their descriptions can be found in Table 3.2.

These ciphers not only added a layer of linguistic complexity to the game but also reflected some grammatical concepts in a way that was tied to the learning outcomes of the game. By making these aspects of Irish grammar an integral part of the gameplay, the game provided learners with opportunities to notice and practise essential language features in an engaging and interactive manner.

Figure 3.14: Examples of ciphers related to the Irish language: ‘Solar Eclipse’ and ‘Accent Bomb’

To support the implementation of these linguistic features, certain Irish NLP tools were used. For example, an Irish Part-of-Speech (POS) tagger was employed to process the text and ensure accurate linguistic handling of noun gender and other grammatical elements.

Cipher	**Description**
Vowel Killer	All vowels in the word have been removed
Vowel Sprout	*All vowels in the word have become accented (fada) vowels*
Double Tail	The last letter in the word has been repeated
Bottom Up	The first letter in the word has been swapped with the last
Accent Bomb	*All accents (fada) in the word have been removed*
Half Half	The first part of the word has been swapped with the rest
Reverse	The word has been reversed
Solar Eclipse	*The ruby words belonging to the feminine Spirit of Fire have lost their first letter*
Lunar Eclipse	*The sapphire words belonging to the masculine Spirit of Water have lost their last letter*

Table 3.2: Ciphers and their descriptions, with Irish-specific ciphers italicised.

Word Gender

Word gender was highlighted in the game to encourage learners to notice this grammatical feature, which is often unfamiliar to English-speaking learners. As part of the game's narrative, nouns were presented in distinct colours according to their gender (see Figure 3.15): blue for masculine nouns (affiliated with the Water Spirit) and red for feminine nouns (affiliated with the Fire Spirit). This colour-coding facilitated learners' awareness of the two distinct noun genders, providing a visual aid that helped reinforce their understanding of this important aspect of Irish morpho-syntax.

Some of the more complex ciphers apply specific effects to nouns of one gender (e.g., Solar Eclipse). This added an extra layer of challenge, as players were required to remember the colour of words they encountered in the game. By integrating this feature into the gameplay, players not only became more familiar with the concept of noun gender in Irish but also gained an advantage in later stages by noticing and recalling the affiliation of nouns with the Water or Fire Spirits.

Figure 3.15: A screenshot illustrating noun gender highlighting shows the blue word 'uisce', associated with the Water spirit (masculine, left) and the red word 'tine', associated with the Fire spirit (feminine, right). The double-tail cipher is applied to the text, transforming 'Tá' into 'Táá' and 'ann' into 'ann'

Power-Ups

In this stage, 'power-ups' were also introduced to enhance the gameplay experience and motivate players (see Figure 3.16.). The original Cipher game featured a scoring system in which each correct answer added points, serving as a motivational strategy for players to collect them. The new power-up feature further utilises the score (now referred to as spirit power), allowing players to exchange it for special abilities (i.e., power-ups) in the game. These power-ups allowed learners to progress through the game even if their language proficiency was low, ensuring that all players could enjoy the game regardless of their current skill level. The goal of this feature was to provide an engaging experience for students who might otherwise struggle with Irish, exposing them to the language in a fun and low-pressure environment. Table 3.3 provides details of each power-up in the game.

Figure 3.16: A screenshot of power-ups in the game.

Magical Eye	**Description**
Psychic Eye	Reveal the colour of all the words in the story
Evil Eye	See the 'truth': If charmed words are found, their true forms will be seen
Cursed Eye	Cursed eye for 7 seconds: Charmed words flicker for 7 seconds
All Seeing Eye	See everything: Charmed words and their true forms flicker for 7 seconds

Table 3.3: Power-ups and their descriptions.

Writing Task

Additionally, a writing component was added to the game to deepen the learning experience. After players successfully identified errors and deciphered ciphers, they were prompted to complete a story by typing an Irish sentence to continue the narrative (see Figure 3.17). If they failed at deciphering a page, they had to reattempt the task with a new set of randomly generated ciphers, further reinforcing their learning. This writing task not only encouraged active participation but also aimed to improve learners' sentence construction and grammar skills through practical application.

Adaptivity

To cater for learners with varying levels of Irish proficiency, adaptivity was added to the game. The adaptive system adjusted the difficulty of the text and the number of

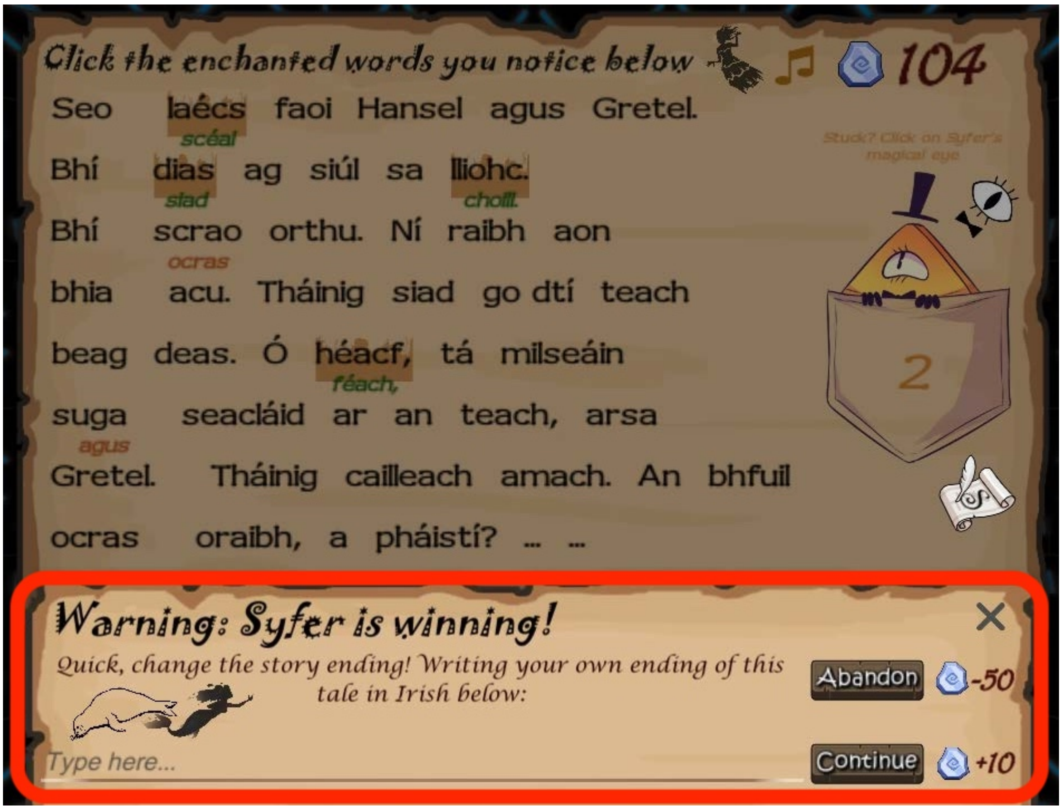


Figure 3.17: A screenshot of the writing component (highlighted with a red rectangle).

ciphers based on the player's performance and background information, such as age, school year, and whether they were from an English- or Irish-medium school. As players progressed through the game and demonstrated their proficiency, the game dynamically adjusted the difficulty, ensuring a continuous learning curve tailored to each individual. Details regarding adaptivity are provided in Chapter 4.

3.4.3.2 Stage 2 Evaluation and Reflection

Feedback received in stage 1, along with the co-design process with TY students, led to expanding the range of ciphers and focusing on Irish folklore and myths instead of everyday textbook prose. This approach enhanced the game's ethos, increased the potential for learning through heightened motivation, and sustained high satisfaction (71.9%), as shown in Table 3.5 in Section 3.5.

The enhancements made during this stage of development resulted in a more engaging and educational experience for learners. The introduction of a culturally rich storyline, combined with language-specific magic spells and adaptive gameplay, helped to engage players with the Irish language while also making the game more accessible to learners of different levels. User feedback showed that these changes were well-received. The narrative and integration of Irish mythology made the game more enjoyable, while the removal of real-world error distractors helped simplify the gameplay.

A two-week user experience study was conducted in an English-medium primary boys' school in Dublin. The study consisted of one 30-minute session per week and involved 64 participants.

Feedback revealed that players liked the game but some found the texts and the ciphers difficult, and many found the free-form story completion element too challenging. Clearly, more support was needed for early-stage Irish learners. With this in mind we explored the potential of AI image generation to create context-specific visual aids to enhance learners' comprehension and engagement. For detailed information on the data and feedback from Stage 2, please see Chapter 4.

3.4.4 Stage 3: AI Generated Image Incorporation

3.4.4.1 Stage 3 Co-Creation and Implementation

In this stage, collaboration expanded to include a primary school teacher. Team discussions prioritised context-specific visual aids to enhance learners' comprehension and engagement, integrating feedback from the previous iteration into the redesign.

The third stage of Cipher's development introduced an important innovation: the incorporation of AI-generated images to enhance the game's visual appeal, improve player engagement and support language learning. This marked a shift in the game's design philosophy, moving from a predominantly text-based game to one that utilised rich visual content to complement and enhance the learning experience.

This stage was developed in response to feedback from earlier iterations, which indicated that the game's reliance on text alone made it more difficult for some learners, particularly those with lower proficiency levels or specific reading difficulties, such as dyslexia, to remain engaged. By introducing images, the game aimed to provide additional context for the stories being deciphered, making the learning experience more immersive and accessible to a broader audience.

AI-Generated Images for Contextual Support

Incorporating images into a language learning game serves multiple purposes. Visual aids can help clarify difficult vocabulary, provide context for learners, and make stories more engaging. For this reason, the decision was made to include AI-generated images to accompany the text on each page of the game. These images were not arbitrary; they were specifically designed to match the content of the story and reinforce the cultural and linguistic elements that learners were encountering.

For example, well-known fairytales, traditional folklore and Irish mythology were central themes of the game, and the AI-generated images reflected these cultural motifs. In Stage 3, the game focused on two core stories: 'Hansel and Gretel', a familiar fairy tale, and an Irish myth, 'The Salmon of Knowledge'. By including relevant images, players could better understand the narratives and immerse themselves in the magical world of the game.

The images were generated using a pipeline process in which initial prompts were fed into AI Text-to-Image Generation tools, and the resulting images were reviewed for accuracy and appropriateness. The prompts were then iteratively refined until the images aligned with the story content and the game's overall aesthetic. This careful process ensured that all images were cohesive and enhanced the storytelling aspect of the game, giving learners a more complete and culturally resonant experience. Refer to Section 5.5 for more information.

Addressing Cultural and Educational Needs

One of the main benefits of incorporating AI-generated images was the ability to align the visual aspects with the game's educational goals, particularly in promoting cultural awareness. As the game's narrative focused on Irish mythology, the AI-generated images played a crucial role in reinforcing cultural context. Since many traditional Irish stories are not widely represented visually online, the use of AI allowed the development team to create unique, culturally relevant images that may not have been otherwise accessible due to copyright restrictions or a lack of resources.

This was particularly important for the Irish mythology tales in the game. The visual representation of 'The Salmon of Knowledge', for example, helped learners connect to the story's cultural significance while also supporting their understanding of the Irish language. AI-generated images were important in fostering this connection, allowing players to visualise the scenes and symbols from Irish folklore as they deciphered the accompanying text.

Additionally, research shows that multimodal learning—the combination of text, images, and interactivity—can be effective in engaging younger learners, particularly in digital environments (Callow, 2012; Schwienhorst, 2002). By incorporating AI-generated images, the game leveraged the power of visual learning to make the language acquisition process more interactive, dynamic, and fun. This multimodal approach was especially useful for learners who may have been struggling with reading alone, giving them another cognitive pathway to understand and retain information.

Removing and Modifying Game Features

As part of the overall enhancement process during Stage 3, certain game elements were temporarily removed or modified based on feedback from previous iterations, as noted in Section 3.4.3.2. For instance, the sentence writing component was removed due to difficulties learners had with typing fully correct Irish sentences. Many players found this task too challenging, particularly in the early stages of their language learning journey. This feature would be redesigned and reintroduced in a later version of the game to better align with the learners' proficiency levels.

Similarly, the adaptivity feature—which adjusted the game's difficulty based on the player's progress—was temporarily disabled. This feature could not be fully tested due to a lack of stories at different levels, and students had difficulty finishing stories within the limited play sessions due to technological restrictions in schools, such as poor internet connections, which frequently forced them to restart the game. During this stage, the decision was made to focus on two specific stories and temporarily remove broader adaptivity in order to refine other aspects of gameplay and collect more detailed feedback.

Visual Integration and Thematic Consistency

To ensure thematic consistency throughout the game, all AI-generated images were carefully curated in consultation with the teacher to align with the magical mythical and child-friendly learning environment that Cipher aimed to create. The visual style of the images matched the tone of the stories, integrating into the overall game design. Each page of the story included an image (see Figure 3.18), ensuring that players had a visual representation of the story's progress and key moments.

Figure 3.18: A screenshot of the reading task in Cipher at Stage 3.

AI-generated images were particularly helpful in maintaining consistency across the story's tone and themes. For example, the visual representations of 'The Salmon of Knowledge' were iteratively generated to evoke Irish cultural symbols, with attention paid to the myth's deeper meaning. The game's use of images not only provided context for learners but also helped reinforce the cultural identity that the game sought to preserve and promote.

In summary, in this stage of the game design, AI-generated images were incorporated to enhance learner engagement and support language acquisition. The visual context provided by the images was intended to assist learners in understanding the stories, particularly when faced with unfamiliar vocabulary or complex sentence structures. These images were designed to offer visual cues that would help learners piece together the narrative while developing their language skills. Moreover, the AI-generated images were integrated to promote cultural learning by visually representing key elements of Irish folklore and mythology. The goal was to motivate learners and foster a deeper connection to the Irish language, creating a more immersive and meaningful learning experience. Further technical details about the AI image generation can be found in Section 5.5.

3.4.4.2 Stage 3 Evaluation and Reflection

The goal in this stage was to reduce the text-oriented feel through AI-generated imagery, enhancing comprehension and making the stories more engaging.

A two-month user experience study was conducted, with weekly 30-minute sessions, at an English-medium primary boys' school in Dublin. A total of 169 participants were involved in this stage. The feedback was generally positive, with players reporting that the game was more engaging and enjoyable with the added visual elements. User satisfaction showed a notable increase in appreciation for the game's visual aspects, with 50.8% liking the images. However, progress-saving and networking issues frequently forced players to restart the game, which negatively impacted the overall gaming experience at this stage. Data and analysis for Stage 3 can be found in (Ward et al., 2023; Xu et al., 2023a).

The learners expressed that the images helped them better understand the context of the stories, as shown in Table 3.5 in Section 3.5, making it easier for them to follow along and stay immersed in the game. In addition, teachers noted that the visuals helped reinforce the language learning process, especially for younger students who may have struggled with text-based tasks alone.

While the AI-generated images were well-received, some feedback highlighted areas for improvement in terms of the game's overall flow and the integration of visuals with gameplay mechanics. There were suggestions to further enhance the gaming and learning experience by making the images more interactive or incorporating animations in future versions.

3.4.5 Stage 4: Gaming and Learning Enhancement

3.4.5.1 Stage 4 Co-Creation and Implementation

Continued collaboration with the teacher improved the learning aspects of the game. Feedback from the previous iteration was incorporated into the redesign, highlighting areas for improvement, such as balancing learning with gaming.

In this stage of Cipher's development, the focus shifted toward enhancing the educational aspects of the game and creating a more culturally immersive and engaging experience for learners.

Refining the Storyline and Game Characters

One of the key improvements at this stage was the development of a more immersive and interconnected narrative. The storyline was expanded to further engage players in the magical world of Irish mythology (see Figure 3.19), deepening their connection to both the language and the cultural content of the game. The game opened with an enhanced visual sequence that depicted the mythical world being enveloped in darkness by the evil Pumpkin, who cast spells that sealed away the Spirit of Knowledge in a cursed book.

Figure 3.19: Screenshots of cultural elements and folklore in Cipher.

In response to this threat, the player assumes the role of a witch, the first playable character (see Figure 3.20), tasked with undoing the Pumpkin's spells and restoring the world by deciphering magical ciphers. The storyline was designed to connect all the game's educational tasks—including vocabulary exercises, reading tasks, and writing components—into a cohesive mission that progresses as the witch gradually unravels the evil spells. This narrative-driven structure was intended to foster a greater sense of immersion and purpose among players, thereby making the learning experience more enjoyable.

In addition to the central witch character, the evil Pumpkin served as the game's primary antagonist (see Figure 3.21), adding a sense of challenge and conflict to the storyline. Throughout the game, the Pumpkin traps mythical animals in different areas of the world. The player must successfully complete language-based tasks to undo these traps and rescue the animals, with each successful task weakening the Pumpkin's spells.

Figure 3.20: Players select the character 'witch' at the start, with more options possible in the future.

Figure 3.21: The evil pumpkin.

Character Life Mechanism

A new life mechanism was introduced in this stage to further gamify the educational tasks (see Figure 3.22). The witch character was given a 'life power' mechanic, which was tied directly to the player's performance in completing language tasks such as deciphering ciphers (i.e., undoing spells) or solving vocabulary puzzles.

Unlike the scoring system already available in the game, each correct answer added points (referred to as 'spirit power'), which could be used for power-ups, while incorrect responses drained life power. This mechanism was designed to connect the language-learning tasks directly to the game's progression, adding an additional layer of engagement by linking the player's success in the game to their performance in educational tasks.

As mentioned earlier, to support learners who might struggle with certain language tasks, the game incorporated power-ups that allowed players to use their in-game points (scoring system) to progress. These power-ups were strategically designed to provide players with a sense of agency, even if their language proficiency was limited. For learners who were not yet confident in their Irish skills, the power-ups served as a tool to continue enjoying the game while still gaining language exposure through gameplay. While this allowed less proficient learners to enjoy the game, it also created opportunities for repeated exposure to Irish, which can foster positive reinforcement and incremental improvement (Smith, 1987; Turley, 2018).

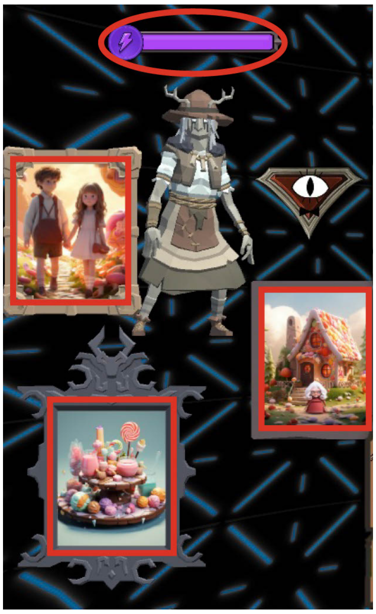


Figure 3.22: The witch's life system highlighted in a red circle and AI-generated images highlighted in red rectangles.

Figure 3.23: The witch's family members' photos.

Figure 3.24: The revealed family photo functions as a magical shield.

Further Incorporation of AI-Generated Images

Building on the initial exploration of AI-generated images in Stage 3, three sequential images per page aligned with the storyline were introduced to enhance comprehension and transform these images into interactive game components (see Figure 3.22).

These images were not just decorative but were deliberately woven into the narrative as part of the game mechanics. In the storyline, the three AI-generated images served as story plot pictures in disguise but were, in fact, photos of the witch's family members (see Figure 3.23), acting as a protection charm imbued with the witch's magic. Before the true photos are revealed, these images provide contextual information related to the story (see Figure 3.22). After the reveal, they function as a shield (see Figure 3.24), also symbolising the witch's desire to save her family, a hidden storyline in the game.

Mechanically, these family photos gave the player additional life power. Each picture grants extra life power, allowing the player to withstand more hits from the Pumpkin's attacks if answering something wrong. Combined with the life power initially obtained from the vocabulary tasks, the witch (i.e., the player) could make more attempts at finding the enchanted words. Each time one of the family photos was used to block a hit from the Pumpkin, the AI-generated picture would appear on the screen and then disappear, symbolising its protective function. If the player ran out of life power entirely, they would need to complete a writing task to revive the witch and continue their progress in the game.

This integration of images and gameplay mechanics helped to reinforce the connection between the narrative and the educational tasks, adding a meaningful layer to the story while also providing players with tangible gameplay benefits.

Vocabulary Learning - 'Letter Brick'

Stage 4 saw the introduction of a new vocabulary learning component, designed to further integrate educational content into the gameplay. Known as 'letter brick', this feature was created to pre-teach certain words related to the reading material that learners would encounter throughout the game. The inclusion of this feature aimed to enhance learners' ability to engage with the reading tasks by building familiarity with the core vocabulary ahead of time.

In the vocabulary section of the game, players were presented with scrambled words alongside magical spells. To solve the puzzle, they needed to correctly rearrange the letters of the word (or 'letter brick', see Figure 3.25 to the left) to form the correct Irish word, which was relevant to the context of the story. This component gamified the process of learning new vocabulary, giving players the opportunity to practise spelling and word recognition in an interactive, low-stakes environment. Additionally, the vocabulary task is a key part of the game mechanics and serves as the source of the witch's life power. Upon completing the vocabulary task, the witch gains a certain amount of life power and then proceeds to the reading part of the game (see Figure 3.25 to the right).

Figure 3.25: Vocabulary task. The word is colour-coded to indicate gender, and the purple lightning symbol represents the life power gained by the witch upon completing a vocabulary task.

The 'letter brick' served as a natural extension of the game's reading and writing components, building a bridge between these tasks and allowing for a more holistic approach to language learning. By introducing vocabulary ahead of time, the game helped learners feel more confident when they encountered these words in reading tasks, reducing the cognitive load associated with reading unfamiliar texts (Liu, 2024).

Enhancing the Writing Task - ‘Word Brick’

One of the most important enhancements introduced in Stage 4 was the improvement of the game’s writing task. In earlier stages, the writing component required players to construct sentences from scratch, which many learners found challenging and overwhelming. In response to this feedback, the writing task was redesigned as ‘word brick’: players were provided with scrambled words and asked to rearrange them into grammatically correct Irish sentences. The word order is randomly generated but occasionally the the words appear in the correct order (see Figure 3.26). AI-generated images are provided to offer additional contextual information.

Figure 3.26: Writing task with an AI-generated image as a visual aid.

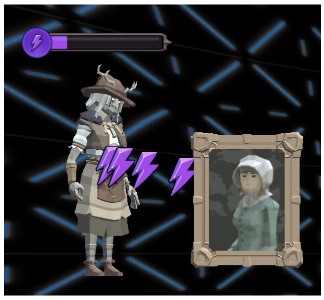


Figure 3.27: The witch revives and regains her power after completing the ‘word brick’ task.

This new approach to the writing task reduced the difficulty of the task, while still encouraging learners to engage with sentence construction and syntax in a meaningful way. The task was positioned as a follow-up to the reading component, allowing players to consolidate what they had learned by forming sentences based on the content they had read. Additionally, the writing task became a revival mechanism in the game: if the witch’s life power was exhausted during the reading tasks, players could complete a writing task to revive her and continue the game (see Figure 3.27). This interconnected structure helped ensure that each language task contributed directly to the overall gameplay experience.

Remove Gender Highlight in Reading Part

In this stage, based on feedback from previous iterations from both students and teachers, the gender highlight feature was removed from the reading tasks but retained in the vocabulary tasks. The removal of this feature in the reading portion addressed concerns that the different colours of words (e.g., Figure 3.28) were distracting to learners. During reading, learners often assumed that the coloured words were the enchanted words they needed to decipher, which was not always the case. By removing this potential distraction (e.g., Figure 3.29), the game allowed learners to focus more fully on reading comprehension without the added visual complexity of the gender highlights.

Figure 3.28: Reading task with colour-coded feature.

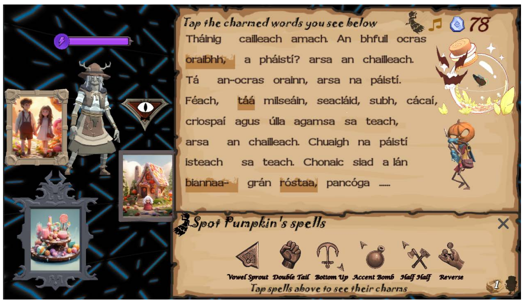


Figure 3.29: Reading task without colour-coded feature.

However, the gender highlight feature (see Figure 3.30) was retained in the vocabulary tasks, where it remained useful for teaching the gender of nouns in Irish. The decision to focus the feature on vocabulary tasks ensured that learners could still benefit from the visual cues related to gender without disrupting the flow of the reading tasks.

Alignment with the Primary School Curriculum

As noted in Section 3.2.3, the vocabulary and reading materials were co-created with primary school teachers, and the 'word brick' writing element was introduced in consultation with them. This collaboration helped align the game with the Irish primary school curriculum, ensuring that the words and structures learners

Figure 3.30: The gender feature in the vocabulary task is highlighted within the red rectangle.

encountered in the game matched those they were learning in school. By integrating the game with the curriculum, the team aimed to provide learners with a pedagogically informed learning experience, allowing them to practise and reinforce their classroom learning through play. The incorporation of learning materials co-created with teachers helped ensure that the game focused on pedagogically sound content. This ensured that the game was effective in improving learners' language skills.

3.4.5.2 Stage 4 Evaluation and Reflection

A three-week user experience study was conducted, with one 30-minute session per week. 31 participants from an English-medium primary boys' school in Dublin took part in this phase. The overall feedback was positive, with a majority expressing enjoyment of the game (77.4%) and a more positive attitude towards learning Irish (45.2%). The improvement of AI-generated imagery incorporation was well-received, aiding in story comprehension (54.9%), as shown in Table 3.5 in Section 3.5. The learners reported that the game was more engaging and that they enjoyed the new storyline, characters, and game mechanics. Teachers also noted that the new vocabulary pre-teaching and improved writing tasks made the game more effective as a learning tool.

In particular, players appreciated the introduction of game characters, life mechanisms and 'letter brick'. The revised writing task was also well-received especially by teachers, and learners found the word brick more manageable than the earlier free-form writing tasks. The game's success in this stage demonstrated its potential to both engage students and improve their Irish language skills. Additionally, teachers highlighted the game's potential to increase student motivation in using the language.

During the experiments, some students with learning difficulties, such as dyslexia, showed interest in playing the game, including some who were exempt from learning Irish. However, these students encountered specific difficulties, particularly in understanding the game rules and completing reading tasks. Their struggles highlighted a gap in accessibility and usability for learners with such challenges. This feedback will be a critical focus for the next iteration in Stage 5, emphasising the need for clearer instructions, reduced text load, audio supports and dyslexia-friendly game design features.

3.4.6 Stage 5: Language Independence and Inclusivity

3.4.6.1 Stage 5 Co-Creation and Implementation

The Cipher team collaborated with speech and language researchers experienced in working with students with learning difficulties to inform the design of new features. The objectives included adaptations for dyslexic learners and preparations for multilingual applications.

In Stage 5, the development of Cipher focused on two core objectives: ensuring the game's language independence and enhancing its inclusivity to accommodate a wider range of learners. This stage marked a significant evolution in the design, with adjustments aimed at making the game adaptable to different languages and accessible to learners with diverse needs, particularly those with learning challenges such as dyslexia.

By decoupling the game's content from any specific language and introducing features tailored to support dyslexic learners, the game was positioned to serve a broader audience. These changes were driven by both pedagogical considerations and a commitment to creating an inclusive learning environment where all learners could benefit from the game's educational potential.

Language Independence

From the beginning of the Cipher project, language independence was a key consideration. Initially designed as a game to help with English text error detection, Cipher was later adapted for Irish language learning in earlier stages. Stage 5 took this adaptability further by redesigning the game's structure to make it more language-independent. This meant that the game could be easily adapted for other languages beyond English and Irish, with minimal changes to the game's core mechanics.

The underlying game design was restructured to separate the language-related content—such as vocabulary, sentences and their AI-generated illustrations—from the game's general framework. This separation allowed the language content to be stored in spreadsheet formats, making it simple to switch between languages by modifying the data without needing to redesign the entire game. The flexibility provided by this architecture enables Cipher to be rapidly adapted to different languages, ensuring that the game could be used in diverse language-learning contexts. This is designed with non-technical users in the development team, such as teachers, in mind, allowing them to make content changes without requiring specialised technical skills.

While the proposed framework supports language independence, it is essential to recognise that language-specific and culture-specific elements may still need to be adapted and customised to fit different linguistic and cultural contexts. This customisation ensures the framework's maximum effectiveness for learners from diverse backgrounds, aligning with the principles of culturally responsive teaching (Gay, 2018).

This language-independent approach not only increased the potential reach of Cipher as a language learning tool but also opened up new opportunities for the game to be customised for specific learner groups, including those studying LCTLs or those in multilingual classrooms. The game's framework could accommodate multilingual interfaces (currently available in Irish, English and Chinese), ensuring that the user interface could be tailored to each target language, providing learners with a smooth experience regardless of their linguistic background (see Figure 3.31).

Figure 3.31: A screenshot of the Cipher login page with the Irish language interface.

Enhancing Inclusivity for Dyslexic Learners

One of the important advancements in Stage 5 was the adaptation of the game for English learners with dyslexia, a group with specific learning needs that require tailored approaches. This development took place during a research internship at the University of Sheffield. Dyslexia presents unique challenges for language learners, including difficulties in reading fluency, spelling and processing text (Rose, 2009). These challenges can make traditional language-learning environments particularly frustrating for dyslexic learners, which in turn can negatively impact their motivation and confidence (Ugwuanyi et al., 2020; Vimochana et al., 2023).

Recognising these challenges, Cipher was redesigned to make the game more accessible to learners with dyslexia. This redesign involved several key adjustments to both the language learning materials and the game rules, ensuring that dyslexic learners could engage with the game in a supportive and low-stress environment.

Dyslexia-Related Ciphers and Simplified Text Difficulty

To address the needs of dyslexic learners, dyslexia-related ciphers were introduced into the game through consultation with speech and language researchers (see Table 3.4). These ciphers were based on common errors that learners with dyslexia are likely to make when reading English, such as letter reversals (e.g., confusion between ‘b’ and ‘d’, or ‘p’ and ‘d’, where ‘bed’ might be read as ‘deb’), omissions (e.g., silent ‘e’ omission, where ‘hope’ might be read as ‘hop’), or substitutions (e.g., vowel substitutions, where ‘pen’ might be read as ‘pin’). By gamifying these specific types of errors, the game allowed dyslexic learners to practise recognising and correcting their mistakes in a fun, interactive way.

Cipher	**Description**
Hidden Harmony	Ch, Sh, or Th in the word have lost their ‘h’
Silent Eva	The silent ‘e’ in the word is missing
Bomb Switch	B, D, P in the word are all jumbled

Table 3.4: Dyslexia specific ciphers and their descriptions.

Additionally, the overall text difficulty in the game was adjusted with the help of speech and language researchers to make it more accessible at the outset. The game began with shorter, simpler text passages and gradually increased in complexity as learners progressed (see Figure 3.32). This adjustment helped mitigate feelings of anxiety or frustration that dyslexic learners might experience when confronted with difficult text from the beginning of their gameplay.

Figure 3.32: A screenshot of Cipher for children with dyslexia.

AI-Generated Text-to-Speech Technology

Another major innovation in this stage for dyslexic learners was the integration of AI-generated English Text-to-Speech (TTS) technology. Dyslexic learners could benefit from multisensory approaches, in which visual and auditory elements are combined to support learning (Javed et al., 2024). The TTS feature provided clear audio guidance on gameplay and reading tasks, allowing dyslexic learners to listen to the text being read aloud while following along on the screen.

This feature enhanced accessibility by reducing the emphasis on reading and allowing learners to focus on comprehension. By hearing the words spoken aloud, learners were able to better understand the text and process the language more effectively. This auditory support also helped dyslexic learners channel their cognitive resources toward completing text-based learning tasks within the game, making it easier for them to engage with the content.

The addition of TTS technology also ensures that Cipher can become a valuable tool for all learners, not just those with dyslexia. The high-quality audio generated for English by the AI created a more immersive learning environment, enriching the narrative experience while also offering practical language support. However, it is important to note that AI-generated voices may increase cognitive load compared to natural human voices (Dinçer, 2022). Further details about the TTS implementation are discussed in Section 5.6. It should also be noted that this dyslexia-focused enhancement was piloted exclusively in English due to the lack of suitable Irish speech technology for the task.

3.4.6.2 Stage 5 Evaluation and Reflection

This stage focused on incorporating AI-generated English audio for game instructions and interfaces in the Irish version (English-language interface) of the game.

Two studies were conducted to evaluate learning gains and user experience:

- Learning Evaluation: A five-week study, with one 30-minute session per week, involved 23 participants from an English-medium primary school for boys in Dublin. This study focused on assessing the learning effectiveness of the game. Details regarding the learning evaluation can be found in Chapter 6.
- User Experience Study: A three-week study, with one 60-minute session per week, included 62 participants from an English-medium primary school for girls in Dublin. This study assessed the user experience and usability of the game. Details regarding the user experience study can be found in Section 5.7.

The English dyslexic version of the game was not tested for logistical reasons. However, plans are in place for future evaluations to ensure this version meets the needs of learners with dyslexia.

The adjustments made in Stage 5 received positive feedback from learners. 47.8% of students liked the AI-generated audio, while 26.1% found it helpful (refer to Table 3.5 in Section 3.5). The integration of AI audio aimed to enhance accessibility for learners. The integration of TTS technology was well-received, with learners reporting that the audio support helped them feel more confident in their ability to engage with the text. Similarly, teachers found that the game provided a useful tool for reinforcing classroom learning, with the added benefit of supporting students with special educational needs.

The overall inclusivity of the game allows it to reach a broader audience, creating a learning environment that was supportive of diverse learning needs while still retaining the engaging, gamified approach that had made Cipher popular in earlier stages. The success of the game's adaptations in Stage 5 opened up new possibilities for further refinements, including the potential to adapt Cipher to other learning challenges, such as dyslexia.

By creating a more inclusive and accessible version of the game, Cipher not only reinforced its educational value but also demonstrated its potential as a multilingual, multi-purpose, and adaptable learning tool. The language independence and customisation options introduced in this stage allowed the game to support learners in multiple languages, while the features tailored to English dyslexic learners made the game a supportive and engaging environment for those who often struggle in traditional educational settings.

In addition, the integration of AI-generated audio delivered a more immersive experience. Feedback from learners and teachers highlighted the need to further improve interactions and enhance game narratives to complement this new feature. As a result, storytelling was refined to create a more interactive, engaging, and enjoyable experience. This refinement paved the way for further leveraging mythology and folklore, expanding their role to capture learners' interest and strengthening their connection to cultural themes in the next stage.

3.4.7 Stage 6: Reinforcement of Cultural Approaches through Virtual Reality

3.4.7.1 Stage 6 Co-Creation and Implementation

In this stage, the Cipher team redesigned the game to enhance interactivity and game narratives with the goal of integrating VR with mythology and folklore. This marked a transformation as the platform underwent its final metamorphosis into a VR experience, elevating the project to the next level of immersive educational gaming.

VR technology was used to create a more immersive and culturally rich learning environment, aiming to enhance the application of the theory of reconnecting to the spirit of language. This stage advanced the use of Irish folklore and mythology as central elements of the learning experience by offering learners a virtual space where they could engage with language in a meaningful and interactive way. The VR environment allows learners to interact with cultural narratives, enhancing both their linguistic skills and their emotional connection to the Irish language.

Integration of Irish Folklore in VR

In this stage, the transition from a 2D learning environment to a fully immersive 3D VR experience was built around the narrative of 'The Salmon of Knowledge', a well-known story in Irish mythology. Learners were placed within the mythological landscape, with tasks focused on solving puzzles directly tied to the story's progression. This approach aligned with the theory of reconnecting to the spirit of language on embedding language learning within cultural and historical contexts.

For example, players were tasked with undoing spells cast on objects integral to the folklore—such as the hazel trees, salmon, and fire—by completing vocabulary challenges (see Figure 3.33). Each successfully solved word unlocked a corresponding part of the narrative, reinforcing cultural connections while supporting language learning.

Interactive Mechanics and Multimodal Learning

The VR game's interactive mechanics played a crucial role in enhancing learner engagement. The use of hand-tracking technology allowed learners to physically interact with the environment, such as rearranging letter tiles to form correct words to 'undo' spells. This kind of physical interaction, coupled with the cognitive task of solving word puzzles, created a multimodal learning experience in which learners

Figure 3.33: Screenshots of hazel trees, salmon, and fire.

engaged with language through both sensory and intellectual channels. In addition, visual and auditory cues—such as animations when spells were successfully broken, background music, and sound effects—enhanced the immersive nature of the game. These multimodal elements not only made the learning experience more engaging but also helped reinforce the cultural context, as players felt more connected to the narrative through sensory feedback.

Cultural and Educational Impact

The VR version of Cipher also sought to strengthen the connection between language learning and cultural heritage by integrating historically and culturally relevant places. Landmarks and mythological sites such as the River Boyne and the Well of Wisdom were incorporated into the game, with in-game signs displaying the names of these culturally important locations (see Figure 3.34). This further reinforced the theory of reconnecting to the spirit of languages by enabling learners to reconnect with the land and history through the place-names and geographic markers embedded in the VR world, adding layers of cultural meaning to the language learning process. This approach aligns with the concept of reconnecting to the spirit of language through land.

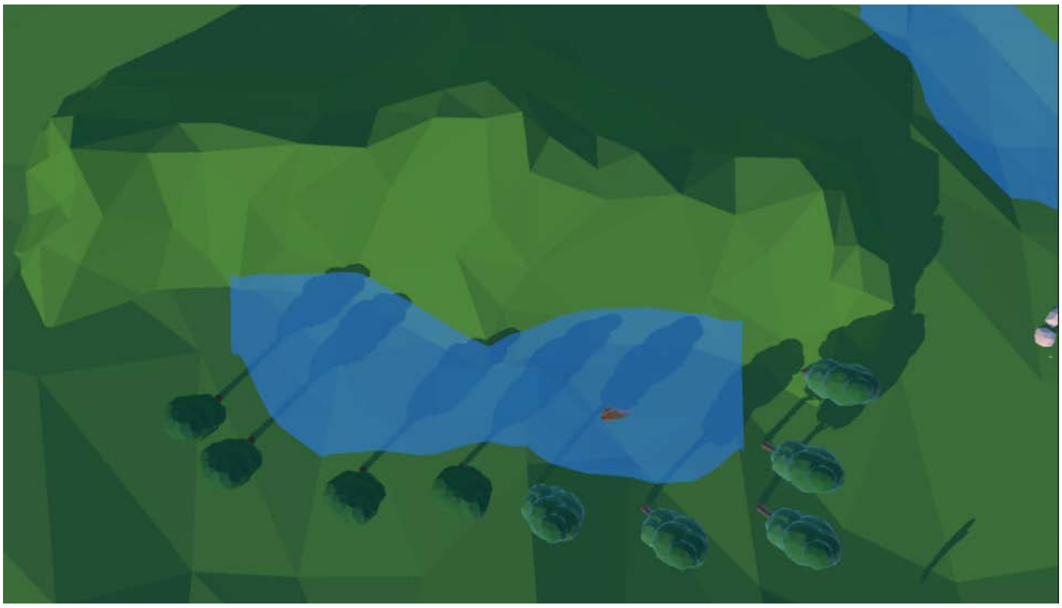


Figure 3.34: A screenshot of the land in VR: the River Boyne and the Well of Wisdom, surrounded by nine hazel trees.

Additional information on the enhancement of cultural approaches in VR can be found in Section 7.2.

3.4.7.2 Stage 6 Evaluation and Reflection

A one-week user experience study was conducted, consisting of a single 10-minute session. 20 participants were involved, including 10 from an English-medium primary school for boys in Dublin and 10 secondary school students (4 boys and 6 girls) from various schools, recruited through the research team's network. Details about the study can be found in Section 7.2.5.

The reinforcement of the theory of reconnecting to the spirit of language through VR in Cipher demonstrated its potential to enhance language learning by creating an immersive, culturally rich environment that encourages meaningful engagement with the language. The VR version was tested with both primary and secondary school students in a pilot study, and feedback indicated that the VR environment improved their engagement and motivation compared to traditional or 2D learning environments. The VR version in Stage 6 received more positive feedback than any of the other stages (see Table 3.5 in Section 3.5).

The immersive nature of the game, combined with its culturally resonant narratives, helped spark an interest in the Irish language and folklore. The game's ability to bring Irish folklore to life in a virtual space highlighted VR's potential as a tool for indigenous language revitalisation. Here is a brief overview of user satisfaction studies across all stages of the game. Detailed results for each stage can be found in Appendix B.

3.5 Overall Results and Discussion

The iterative development process, informed by pedagogical considerations, learner feedback, stakeholder input, and technological advancements, has refined Cipher into a game that balances educational value with engaging gameplay, particularly for less-resourced languages and varied learner needs. Figures 3.35 and 3.36 show photos of the Cipher experiment conducted in classrooms. Through its evolution, modifications were made to enhance language learning and game experience, with particular emphasis on incorporating AI technologies, gamified elements, addressing the diverse needs of learners.

Figure 3.35: Students play Cipher in pairs.

Figure 3.36: Students play Cipher individually in classrooms.

Table 3.5 summairses the overall user satisfaction in the various stages. In addition, a comparative user study was conducted within Stage 5 and between Stages 5 and 6. For the other stages, each was treated as an independent test. More details about the comparative analysis within Stage 5 can be found in Section 5.7, and the comparison between Stages 5 and 6 is provided in Section 7.2.

Question	**Stage 2 Post (n=64, 2-week) 2022**	**Stage 3 Post (n=169, 2-mth.) 2023**	**Stage 4 Post (n=31, 3-week) 2023**	**Stage 5 Post (n=23, 5-week) 2024**	**Stage 6 Post (n=20, 1 week) 2024**
Did you like playing the game? *Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)*	46 (71.9%)	85 (50%)	24 (77.4%)	15 (65.2%)	20 (100%)
How do you feel about learning Irish (after playing the game)? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	36 (56.3%)	63 (37.3%)	14 (45.2%)	N/A	N/A
Do you think you learned anything while playing the game? *Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5).*	33 (51.6%)	59 (34.5%)	20 (64.5%)	15 (65.2%)	14 (70%)
What do you think about learning Irish through the game? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	40 (62.5%)	81 (48.2%)	17 (54.9%)	13 (56.5%)	20 (100%)
How would you compare learning or reading Irish through the game to normal classroom teaching? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	47 (73.5%)	107 (63.3%)	23 (74.2%)	19 (73.9%)	20 (100%)
Do you like the images in the story? *Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)*	N/A	86 (50.8%)	17 (54.9%)	N/A	N/A
Do the images in the story help you understand the story? *Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)*	N/A	46 (27.2%)	14 (45.2%)	N/A	N/A

Table 3.5: Cipher game user satisfaction across stages in a boys' school. **Note:** User satisfaction is assessed by combining responses of 4 (positive) and 5 (very positive) on the Likert scale.

3.6 Overall Findings and Implications

High user satisfaction throughout its development phases underscores Cipher's capability to captivate learners' attention, and successfully navigate the challenge of making educational content engaging without diminishing its educational value—a feat akin to avoiding the 'chocolate-covered broccoli' scenario (Hopkins and Roberts, 2015).

The insights gathered to date affirm the feasibility of integrating a digital game like Cipher within primary school settings. Several key features help to ensure that the process is successful. A shift from (old) laptops to more accessible tablets improved the user experience. Ensuring that the game's content aligns with the curriculum and is tailored to the language proficiency levels of the target student cohort is crucial for its relevance and effectiveness. It can potentially transform the language learning experience, increase student engagement and foster a positive disposition towards the language being studied. The latest VR version achieved the highest satisfaction ratings overall, highlighting the potential of using VR to further advance research and marking the transition of Cipher into secondary school environments. This positive reception underscores the importance of immersive technologies in educational settings, particularly for engaging students with less commonly taught languages like Irish.

Some of the challenges we encountered include the difficulty of adhering to the standard frameworks for evaluating the gameplay experience due to constraints such as limited gameplay sessions for children in the class and the impracticality of long surveys for this audience. Consequently, surveys were shortened to include a subset of questions from study (Bul et al., 2015) to fit the restricted time frames and retain the essence of user feedback, as detailed in Section 4.4, the initial user experience study in Stage 2.

3.7 Ethics

The ethical considerations for the development and deployment of the Cipher game were addressed in compliance with Dublin City University's Research Ethics Committee (REC) guidelines. The ethics application was submitted to the REC, which reviewed and approved the project. Given the involvement of participants under the age of 18, including young learners from primary and secondary schools, specific ethical protocols were adhered to ensure their protection. Permission and consent were obtained from school principals and teachers, after which consent forms were adapted for children and distributed through teachers, along with parental consent forms. Copies of the consent forms and the plain language statement are included in Appendix A.

Data collection adhered to strict confidentiality and data protection standards. No personally identifiable information was collected and all data were anonymised to protect participants' identities. The ethical conduct of this research was maintained through careful adherence to REC guidelines, ensuring that all participants were treated with respect and their data handled with confidentiality.

3.8 Limitations

All tests displayed in Table 3.5 were conducted in the same primary school, except for the VR test, which involved secondary school students. The primary school is a public boys' school, representing a typical Irish primary school. For comprehensive results, a test was conducted in a private girls' primary school during Stage 5, which has more resources compared to the boys' school. The comparative results of these tests can be found in Section 5.7 (comparative analysis section). Aware of the novice effect for VR due to the short duration of the experiment, further experiments are needed to evaluate the effectiveness of Cipher VR comprehensively.

3.9 Summary: Addressing Research Question 3.1

This chapter addressed **RQ 3.1: How can language learning pedagogy be integrated into Digital Game-Based Language Learning (DGBLL) to support Less Commonly Taught Languages (LCTLs)?** Through the iterative cycles of game design and enhancement of Cipher, this research highlights the importance of a learner-centred, co-creative Design-Based Research process that integrates pedagogical principles with technological innovation.

Cipher's progression demonstrates a successful fusion of educational objectives and cultural immersion in DGBLL, creating an engaging platform that boosts motivation for language learning and strengthens cultural connections while integrating technology with linguistic and cultural backgrounds. The incorporation of culturally informed elements and curriculum-aligned tasks showcases how DGBLL applications can bridge the gap between language pedagogy and the unique challenges of LCTLs.

The chapter emphasised the iterative design framework, including the important roles of student and teacher feedback as well as expert insights, which informed refinements to usability educational impact. Furthermore, the ongoing incorporation of pedagogical principles and technological advancements aims to increase its impact, positioning Cipher as a model for similar initiatives in other low-resource language contexts across diverse linguistic and cultural landscapes.

Chapter 4 starts by elaborating on how the original Cipher, which had been used for English language error detection, was repurposed as a tool for learning Irish and other LCTLs, covering progression Stages 0, 1 and 2.

Chapter 4

Repurposing Game Resources: A Green Approach for Low-Resource Languages

This chapter focuses on the adaptation of a game from a high-resource language to address the challenges of language learning for low-resource languages. As discussed in Chapter 2, the increasing popularity of Digital Game-Based Language Learning (DGBLL) stems from its potential to provide both an engaging gaming experience and an effective language learning environment. This dual function is particularly valuable for minoritised languages and communities, where conventional educational methods often face greater challenges in maintaining learner motivation and engagement (Anyichie and Butler, 2023). Furthermore, for low-resource languages, the lack of resources presents substantial challenges when developing Computer-Assisted Language Learning (CALL) systems. This chapter advocates for a green approach to CALL development, which emphasises the reuse and repurposing of available materials (Ward et al., 2019b). The aim is to repurpose an existing game designed for dominant languages and adapt them to meet the needs of learners in low-resource languages, such as Irish, while also exploring the broader applicability for other similar languages. This chapter outlines the importance of these adaptations and the specific challenges encountered in creating such resources for minoritised languages like Irish.

4.1 Repurposing Game Resources

4.1.1 DGBLL Integration

As noted in Chapter 2, the integration of digital technologies into education has reshaped traditional learning paradigms, offering innovative methods to enhance student engagement and learning effectiveness. Among these technologies, DGBLL has emerged as a promising approach, combining the immersive nature of digital games with educational content to make learning both enjoyable and effective (Chowdhury et al., 2024; Janebi Enayat and Haghighatpasand, 2019).

As highlighted in Chapter 2, developing CALL resources for languages like Irish presents distinct challenges. These challenges arise from the limited availability of both technological and linguistic resources, making it difficult to assemble the multidisciplinary teams typically required to create effective educational tools (Ward, 2015b). To address these constraints, this research repurposed existing game resources as a foundational starting point to develop a DGBLL tool for Irish language learners. By leveraging pre-existing game structures, we minimised the complexity and cost associated with developing CALL applications for low-resource languages, enabling a focus on other crucial tasks, such as designing learning materials for the game.

Once this foundation was established, the project expanded in a more holistic direction during later stages, incorporating additional resources and expertise from various fields to enhance its scope. For details on each stage, refer to Figure 4.1. Ultimately, repurposing game resources for Irish DGBLL demonstrates how existing technologies can be adapted to support low-resource languages in overcoming technical and pedagogical barriers. This approach highlights the adaptability of digital games in supporting low-resource languages and showcases the potential for their use in a wide range of contexts.

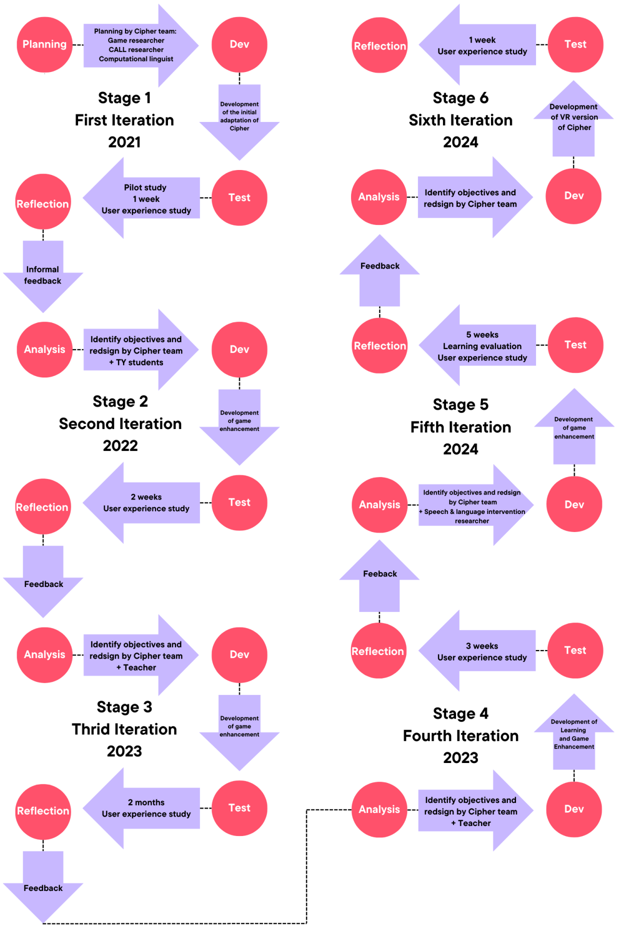


Figure 4.1: Diagram illustrating iterative cycles of Cipher.

4.1.2 Green Approach

A green approach to DGBLL development emphasises reusing existing resources where possible and repurposing them for another game. This strategy is particularly important for low-resource languages, where developing new materials can be time-consuming and costly (Ward et al., 2019b, 2022). For instance, *WordBricks* was originally designed for English and later adapted for Irish (Ward et al., 2019a). Likewise, *Digichaint* (Ní Chiaráin and Ní Chasaide, 2016b) was adapted from the German game *The Language Trap* (Peirce and Wade, 2010) for Irish learners. In the case of Cipher, the original Cipher game was developed for English. There was an opportunity to repurpose the original Cipher game into one that could be useful and enjoyable for learners of Irish. Some core elements of the game such as the steganography feature and scoring systems were retained, while new features, including vocabulary task, game characters and life systems, were added in the later stages (i.e., Stages 3 and 4) after the adaptation phase (i.e., Stage 1). The Cipher Engine (Ward et al., 2022) was proposed to be as language-independent as possible, meaning that the Cipher framework could be repurposed for other languages in the future. In essence, the green approach brings two primary advantages: first, it enables a faster turnaround time in the design and development of Cipher, and second, it creates a scalable framework that can be extended to other languages in the future. This model paves the way for a more inclusive approach to language learning technology for low-resource languages.

4.1.3 Cipher Engine

As noted in Chapter 3, the development of Cipher: Faoi Gheasa [1] was based on the original Cipher game (Xu and Chamberlain, 2020) for advanced level English language users (B1 - C2, on the Council of Europe CEFR [2] scale). Cipher was a crowdsourcing game designed for identifying errors in text which uses the idea of 'games with a purpose' (Von Ahn, 2006). Error spotting was gamified such that people were encouraged to spot errors in texts through the game. While playing the game, players are making annotations to the text, and thus data is collected for further analysis. The results showed that people could easily notice text errors in the game and it is therefore possible to identify errors using a game. Moreover, feedback from users indicated that Cipher was fun to play and has the potential to help language learning. Cipher: Faoi Gheasa was adapted to support Irish language learners of A2 - B1 level. A new storyline, new game features and elements, and updated rules were added to the original Cipher engine to encourage language learning and facilitate in-game data collection. The theme of 'reconnecting to the

[1] *Faoi Gheasa* translates to *Under a Spell* in Irish. The Irish version of Cipher, formally named Cipher Faoi Gheasa, is referred to simply as Cipher throughout this thesis for brevity.

[2] `https://www.cambridgeenglish.org/exams-and-tests/cefr/`

spirit of the language' (Napier and Whiskeyjack, 2021) functions as the cultural background behind the game design. Moreover, language-independence remains a key design feature of the project. This is to make sure our work can be adapted to other Less Commonly Taught Languages (LCTLs). It should be noted that the Cipher engine is a framework designed to be adaptable to other languages, while Cipher is the game derived from the framework, specific to a targeted language.

4.2 Game Mechanics

During the adaptation of Cipher from English to Irish, three language skills were emphasised in the game: noticing, reading, and writing. These skills are embedded within the game tasks and aligned with the storyline of 'reconnecting to the spirit of the language'. The storyline is as follows:

1. There is an evil game character whose goal is to make ancient tales unreadable to people by casting spells upon the tales in which many ancient mythological creatures dwell. The evil spirit wishes to make people forget the tales and ensure that these mythical beings will eventually vanish as their existence is based on people's belief in them. The aim of the player is to defeat the evil spirit.

2. The players need to read stories and find the enchanted words and identify the spells that were cast upon the words.

3. The design of the spells is inspired by the idea of steganography following the original Cipher game. A spell changes certain words (these modified words are known as enchanted words in the game) in the story in a particular way so that the players can identify a spell by finding patterns of errors in the story. This can help with the practice of spelling and reading. For ease of understanding, we also refer to spells as ciphers.

4. Some spells (ciphers) are associated with grammatical information (e.g., word

gender), which is designed to help learners get to know more about this aspect of vocabulary.

5. If players fail to find a spell, they will be asked to change the ending of the story (i.e., rewrite the last sentence of the story) in order to prevent forgetting the story and the magical beings involved. This is designed to help with the practice of writing.

In addition, power-ups are available to help players who get stuck. Besides adding more fun to the game, the design of power-ups enables players with little or no knowledge of the language to still be able to enjoy the game. In summary, the task of the player in the game is to find the enchanted words and identify spells cast by the evil game character and thereby save the ancient spirits and the stories. The incentive in the game is to gain spirit power, which serves as a token and functions as the game's scoring system. Players will gain tokens if they do the 'right things' in the game, which includes finding enchanted words (i.e., errors), finding spells (i.e., ciphers) and continuing the story (i.e., writing sentences). Players' tokens will be deducted if they click on a word that is not an error, or click on a spell that is not 'responsible' for the enchanted words, and also when they use power-ups or choose to abandon a story (i.e., skip a story).

Cipher: Faoi Gheasa adapts dynamically to a player's language level. If a text is easy for a player, i.e., if they identify all enchanted words and spells, they are shown a more difficult text the next time. Conversely, if a text is too difficult for a player, they are shown an easier text the next time. Furthermore, the difficulties of spells are adaptive. The choice of spells used in the game text is reflected in players' performance. Figure 4.2 shows the logic of the adaptability of Cipher: Faoi Gheasa.

4.2.1 Database

The database plays a crucial role in ensuring that Cipher: Faoi Gheasa operates smoothly by managing data flow and supporting essential game features. By building

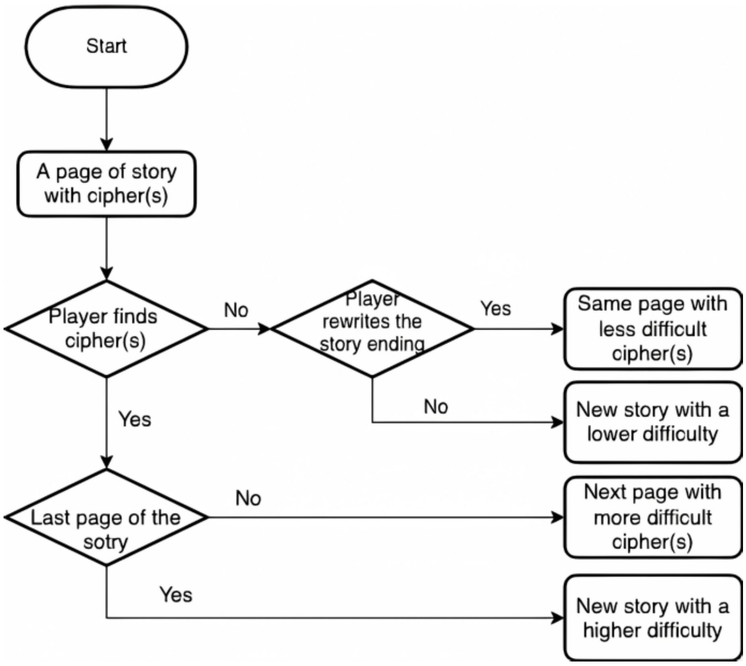


Figure 4.2: Cipher adaptivity diagram.

on the original Cipher game's database structure, the adaptation for Irish introduced several new elements to the database to better support language learning features, such as enhanced tracking of game progress, more comprehensive logging of word-related information during the reading task, and sentence-related information during the writing task. The use of this database is essential for both in-game interactions and the collection of data for future improvements and evaluation (e.g., stealth assessment).

We used MySQL Server [3], a free and open-source relational database management system (MySQL, 2024). The database was hosted on a Windows virtual machine in Microsoft Azure [4] to enable data communication between the game client and the server. This setup supports real-time in-game interactions, such as tracking user progress, which is crucial for both gameplay and learning analytics. Each player action, whether identifying a cipher (i.e., spell) or progressing through game levels, is recorded and assessed. This continuous monitoring enables dynamic learning

[3]`https://www.mysql.com/`
[4]`https://azure.microsoft.com`

adaptation, ensuring the game adjusts to each player's language proficiency and overall game competence. For example, as the game monitors a player's success in identifying errors or ciphers, it dynamically modifies the difficulty of subsequent texts and tasks. This allows learners to progress at their own pace, providing a personalised and engaging experience that fosters language acquisition through incremental challenges, ultimately guiding players to reach their Zone of Proximal Development (ZPD).

The database also plays a central role in managing various types of player information—such as login credentials, player scores, game progress, and game level—and integrates these with the overall game mechanics. This structure enables the game to maintain an adaptive learning curve by modifying task difficulty based on player performance. Each interaction is stored in a specific table, with each serving a distinct function in the game. The key tables include the following:

- Annotation Table: Stores each annotation (e.g., clicks on words during reading tasks), allowing for analysis of player interaction with the game. (see Table 4.1).
- MissInfo Table: Logs 'enchanted words' missed by players, contributing to the game's adaptive mechanism by identifying areas where learners struggle (see Table 4.2).
- PlayerInfo Table: Holds static information about players, such as age and school year, which can be used to personalise learning experiences (see Table 4.3).
- PlayerData Table: Tracks dynamic data such as scores, game levels and unlocked content, ensuring that learners can resume from their last progress point and that game difficulty adapts accordingly (see Table 4.4).
- Sentence Table: Captures sentences typed by players during writing tasks, providing crucial insights into language production and learning outcomes (see Table 4.5).

Detailed information for each table is provided below:

Database name: mygamedb.

In all tables, all fields store strings using the VARCHAR datatype, except for the Id field, which uses the INT datatype to store numeric values. For example, the Annotation entity represent a row of data and includes fields such as WordID, which stores the unique identifier (e.g., 'w0') for each word in a story.

Annotation	
Field	**Description**
Id	The unique identifier for each row of data
PlayerID	The player's ID
WordID	The ID of the clicked word
StoryID	The ID of the story which the word is from
Cipher	The Cipher applied to the word. (The list of ciphers and their descriptions is provided in Table 3.2, Section 3.4.3.1)

Table 4.1: Annotation table stores information about each annotation made by players. Each annotation represents a word clicked by the player during the reading task in the game.

MissInfo	
Field	**Description**
Id	The unique identifier for each row of data
PlayerID	The player's ID
WordID	The ID of the clicked word
StoryID	The ID of the story which the word is from
Cipher	The Cipher applied to the word

Table 4.2: Missinfo table records the 'enchanted words' missed by the player during the reading task.

The database's ability to store and analyse detailed data on both player performance and game interactions is essential for stealth assessment. This assessment will be a key component in future development plans, allowing for continuous evaluation of player learning while maintaining an immersive gaming

Player	
Field	**Description**
Id	The player's ID
Account	The player's username
BirthYear	Year of birth (used to calculate the player's age)
SchoolName	Name of the school
SchoolYear	Grade level
RegisterTime	Registration time

Table 4.3: Playerinfo table stores basic player information, which typically does not change over time.

PlayerData	
Field	**Description**
Id	The player's ID
Score	The player's score
GameLevel	Game level
GameProgress	Game unlocking progress
LastPlayProgress	The last level played before exiting the game

Table 4.4: PlayerData table stores the player's saved in-game data and updates based on the player's progress.

PlayerLoginInfo	
Field	**Description**
Id	The player's ID
Password	The player's password
LastLoginTime	Last login time

Table 4.5: PlayerLoginInfo table stores the player's username and password, which are used for login purposes.

Sentence	
Field	**Description**
Id	The unique identifier for each row of data
PlayerID	The player's ID
SentenceID	Sentence ID
StoryID	Story ID
ChapterID	Chapter ID
TypedSentence	The sentence typed by the player

Table 4.6: Sentence table records the sentences typed by the player during the writing task.

Story	
Field	**Description**
Id	The unique identifier for each row of data
Title	Story title
Difficulty	Story difficulty
Length	Story length
Source	What source the story is from

Table 4.7: Story table stores information about each story.

experience. As defined by Shute (2011), 'stealth assessment' refers to gathering evidence of learning through in-game actions in a way that does not interfere with the flow of gameplay. This approach contrasts with more overt assessment methods, such as vocabulary tests, which are used in this research (see Section 6.2). In future iterations, additional tables such as a Vocabulary Table (see Table 4.8) could be introduced, enabling further granularity in tracking language acquisition.

Vocabulary	
Field	**Description**
Id	The unique identifier for each row of data
PlayerID	The player's ID
WordID	Word ID
StoryID	Story ID
ChapterID	Chapter ID
TypedWord	The word typed by the player

Table 4.8: Vocabulary table records the vocabulary typed by the player during the vocabulary task.

This database approach offers a flexible framework that can be adapted for use with other languages. By utilising detailed in-game data, Cipher: Faoi Gheasa helps create a more personalised learning experience for each player. The adaptability of the framework not only enhances the educational impact for individual learners but also contributes valuable data for broader language evaluation research. As more data is gathered, future iterations of the game can be refined, further improving its effectiveness as a tool for language learning across different linguistic contexts.

4.2.2 Building Language Flexibility with XML

XML technologies have long been recognised for their potential in the creation and reuse of language learning materials (Ward, 2002). In the Cipher project, this potential was realised by reusing the original XML structure from the English version of Cipher to store and manage Irish text in the reading task within the game (see Figure 4.3 to the left). The XML files contain essential information, including story titles, content and specific word details, such as word ID, Part-Of-Speech (POS) tags, base forms and standard forms (see Figure 4.3 to the right). This structured format allows for efficient handling and manipulation of textual data, a crucial aspect in the DGBLL environment.

Despite the limited availability of NLP tools for Irish, the XML structure made it possible to process text data by utilising existing Irish language resources. The use of XML not only enabled the Cipher engine to handle Irish texts but also ensured that the engine remained adaptable to other languages. By keeping the framework language-independent, the XML structure facilitates easy adaptation for other low-resource languages, allowing for the creation of new versions of Cipher simply by inputting the relevant text data for a target language.

Figure 4.3: Cipher reading task and XML supplying text for the game.

One of the key advantages of using XML is its flexibility in managing linguistic data, regardless of the specific language. In the case of Cipher, the structured nature of XML allowed the project to handle variations in grammar, orthography, and other linguistic complexities inherent in Irish. This ability to store and manipulate linguistic information at a granular level is important for maintaining the integrity of language-specific learning materials while still adhering to a broader, scalable framework. The flow of text data processing is shown in Figure 4.4.

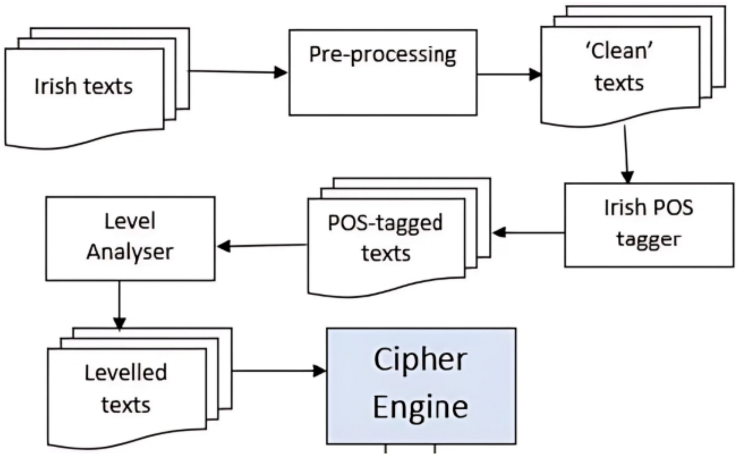


Figure 4.4: Text data processing flow.

However, one limitation of this approach is that managing the XML file is restricted to technical users on the development team, such as software developers. In later stages, the language-related data (e.g., language interfaces, vocabulary, and sentence data) is stored in separate spreadsheets, reducing the technical demands and allowing non-technical users to modify the content more easily.

In summary, the reuse of XML in Cipher ensures both efficiency and scalability, as it allows the project to leverage existing resources while maintaining the adaptability required to extend the framework to additional languages. As long as the necessary linguistic data for any target language is structured in the XML format, the Cipher engine can be employed to create language learning games with minimal additional development, making this a powerful technique for less-resourced languages.

4.3 Challenges and Solutions

This section highlights some challenges in the game adaptation process and outlines potential solutions.

4.3.1 Limited Technology for Irish

Irish, like many LCTLs, suffers from a scarcity of Natural Language (NLP) Processing tools and resources. While major languages like English benefit from an abundance of NLP tools, their availability for Irish is limited, making the development of CALL resources for the language more complex (Ward et al., 2019b). For instance, text difficulty classifiers and other language processing tools that are readily available for major languages need to be specifically developed or adapted for Irish (Mc Cahill et al., 2024).

To address this technological gap, it is crucial to integrate existing NLP tools for the Irish language and adapt NLP resources from other major languages. This involves leveraging part-of-speech taggers, AI text classifiers, and other NLP techniques to enhance the CALL application for Irish. For more details on how these technologies are being utilised and further developed, refer to Section 5.2.

4.3.2 Limited Language Resources for Irish

The scarcity of language resources poses another significant challenge. As a low-resource language, Irish lacks extensive repositories of digital and educational materials available for more widely spoken languages. This limitation makes it difficult to create engaging and culturally relevant content for learners.

To mitigate the lack of resources, existing language materials can be repurposed and adapted. This approach includes utilising digital archives such as the Dúchas project, which houses a vast collection of folklore, myths, and stories. For instance, stories from The Schools Collection of the Irish National Folklore Collection have been adapted for use in the Cipher game (Ó Cleircín et al., 2014). This involves modernising the language and integrating culturally relevant narratives to enhance learner engagement and cultural connection (Daly, 2010; Ó Cleircín et al., 2014). This approach not only provides a rich source of authentic language material but also aligns with the theory of reconnecting learners with the spirit of the language through culturally informed content. Further details on this process are discussed in Section 7.1.

In summary, addressing these challenges requires a strategic blend of leveraging existing technologies and resources, interdisciplinary collaboration, and innovative adaptation techniques. These solutions are elaborated in the following chapters, highlighting the potential of integrating technology and cultural elements to enhance language learning for LCTLs like Irish.

4.4 User Experience Study

References: This section is mainly based on (Xu et al., 2022).

The choice of a standardised survey was grounded in its ability to comprehensively assess user experience across four dimensions: gaming experience, learning experience, adaptivity, and usability, following the framework established by Law and Sun (2012). This framework is particularly suitable for evaluating adaptive digital games and it aligns with the study's focus on balancing learning and gaming.

The standardised evaluation framework used, as proposed by Law and Sun (2012), includes the following dimensions:

- Gaming Experience: This dimension focuses on the player's engagement and enjoyment during gameplay, encompassing elements such as immersion and challenge.

- Learning Experience: This measure evaluates the integration of content appropriateness, clarity of goals, and feedback mechanisms that facilitate meaningful learning.

- Adaptivity: Adaptivity addresses the game's responsiveness to individual player needs.

- Usability: Usability examines whether game mechanics are intuitive and accessible to users without causing frustration or confusion.

Survey questions were crafted to capture the four aspects and responses were analysed and the findings indicate that participants were satisfied with the game. The user experience study was conducted at an English-medium boys' primary school in Ireland. Participants are students aged 10-12 years from the 4th, 5th and 6th grades with each grade having three classes of about 30 students. There was a game session for each of the nine classrooms on one day in two successive weeks. The school Wi-Fi facility was used to meet the internet requirement for playing the game. The participants played the game, mostly in pairs, on laptops provided by the primary school where the experiment was conducted and the university where the researcher is based. Two questionnaires were designed to collect participants' feedback. Both were issued through Google Forms. We asked the participants to fill out a short questionnaire after the first session, which gave us an overview of user experience and helped us identify issues encountered. Before the session in the following week, we addressed the problems highlighted in the feedback and improved the game where necessary. In the second week, the same participants took part and afterwards were asked to fill out a questionnaire regarding gaming experience, learning experience, adaptivity and usability. During both sessions, researchers were in the classrooms with the participants to answer any questions they had about the game and questionnaires. See Figure B.1 in Appendix B for further details.

We analysed the players' ratings of satisfaction after playing the game, focusing on gaming experience, learning experience, adaptivity and usability, following the method used in the study (Law and Sun, 2012). The answer categories are based on a 5-point Likert scale (1 = very negative; 5 = very positive). The two highest scores (4 = positive and 5 = very positive) were considered as a positive response.

Figure 4.5: Students playing Cipher on laptops during a computational thinking workshop. The experiment discussed in this section took place in a boys' primary school but no photos were taken during the process.

The satisfaction rate was recorded for each question. Overall, the general gameplay experience was positive with 34.4% of students describing it as "fun", 17.2% describing it as "challenging", 15.6% describing it as "boring", and 10.9% describing it as "easy". Details regarding questions and ratings of satisfaction can be found in Table 4.9.

Although only 51.6% of the participants indicated that they learnt something while playing the game, 62.5% of the participants were positive about learning Irish through the game. 59.4% of the participants were willing to read the stories in the game. Furthermore, some of the valid Irish sentences typed into the game by the players, to continue an unfinished story, showed that they read and understood the story in the game.

Regarding the difficulty level of the Irish language used in the game, most students felt that the level was "about right" (46.9%), followed by 25% who felt it was "easy", and 14.1% who felt it was difficult. In answer to the question "Did you find the game easy to play?" 57.8% responded positively. Regarding the question "What problems hindered your gameplay?", the participants reported several usability issues, including poor Internet connection, repeated game tutorial, and login issue, etc. The results regarding student engagement of learning Irish through the game were promising. A

Question	**Satisfaction (n = 64) positive (percentage)**
Did you like playing the game? *Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)*	46 (71.9%)
What do you think of the storyline in the game? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	38 (59.4%)
How willing were you to play the game? *Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)*	47 (73.5%)
Would you like to play the game more often? *Definitely no (1), No (2), Maybe (3), Yes (4), Definitely (5)*	40 (62.5%)
What do you think about learning Irish through the game? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	40 (62.5%)
How willing were you to read the stories in the game? *Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)*	38 (59.4%)
How would you compare learning or reading Irish through the game to normal classroom teaching? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	47 (73.5%)
How do you feel about learning Irish after playing the game? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	36 (56.3%)
Do you think you learned anything while playing the game? *Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)*	33 (51.6%)
What do you think of spells (ciphers) in the game? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	44 (68.8%)
What do you think of the Irish stories in the game? *Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)*	39 (60.9%)

Table 4.9: Proportion of participants' ratings in terms of gaming experience, learning experience, and adaptivity. **Note:** User satisfaction is measured by combining responses of 4 (positive) and 5 (very positive) on the Likert scale.

majority of participants (73.5%) gave positive responses when comparing learning or reading Irish through the game to traditional classroom teaching and 73.5% of the participants were willing to play the game. Interestingly, several students who do not study Irish were able to play the game and even enjoyed it (though they relied heavily on power-ups), indicating that it was a positive language exposure activity for them. This demonstrates that the Cipher Faoi Gheasa game is successful in combining entertainment and educational aims. In addition, some teachers provided verbal feedback which indicated that the students were very engaged with the game. Some of the teachers even started to give extra language support to some of the students when they had problems finding errors or understanding the story in the game, which can be a new model of language teaching and learning in the future classrooms. However, it is important to consider the potential influence of the Hawthorne effect, a phenomenon where the novelty of the intervention may influence participants' responses, potentially leading to a positive bias in the experiment results (Adair, 1984).

Originally, we prepared an extensive and standardised survey to evaluate the gaming experience, learning experience, adaptivity and usability, based on the framework outlined in research (Law and Sun, 2012). However, the length of the survey proved impractical for our target group, given the limited time available during school game sessions. Many children were either unable to complete the survey or chose not to, which rendered the survey ineffective. To address this, we shortened the questionnaire while ensuring it still captured key areas of the gaming experience, learning experience, adaptivity and usability. This focused approach allowed us to gather essential feedback without overburdening the participants. This revised, more concise survey became the first official survey we conducted, and it served as the foundational framework for subsequent testing phases. Other challenges in this initial test included outdated devices (e.g., heavy and old laptops obtained from the primary school where the experiment was conducted and the university where the researcher is based, see Figure 4.5) and limited internet access in the school, which caused some usability issues. The issues encountered during the experiment were documented and steps were taken to improve the situation for future school tests.

4.5 Language Independence: Adaptations in other languages

It can be more challenging to develop DGBLL resources for LCTLs and therefore, where possible, DGBLL developers should aim to develop resources that are language-independent. In other words, the framework should be decoupled from any specific language, enabling a plug-and-play approach where language-specific modules can be easily integrated into the core framework. By adopting this approach, developers can create DGBLL resources tailored to a specific language simply by adding the necessary language components. While pedagogical issues may arise due to the diversity of human languages, a language-independent approach offers notable advantages, particularly for LCTLs. This design philosophy was central to the development of the Cipher engine.

The Cipher engine was refactored to be language-independent, allowing it to be used for other languages apart from Irish. Even if NLP tools are not available for a given language, the Cipher engine can still generate a Cipher game from raw text for that language, making it a flexible and powerful tool for developing DGBLL resources for LCTLs. However, as outlined in Chapter 3, it is important to adapt the cultural aspects of the targeted language to ensure it aligns with a culturally responsive framework, thus fully supporting its language-independent design.

4.5.1 Cipher for Nawat

Nawat, the last remaining natively spoken Nahuan language in Central America, is an indigenous language of El Salvador currently classified as endangered (Matthew and Bannister, 2020; Salgado, 2023). Although there are no NLP tools for the language, a manually tagged XML file can be passed to the Cipher engine to create the Nawat

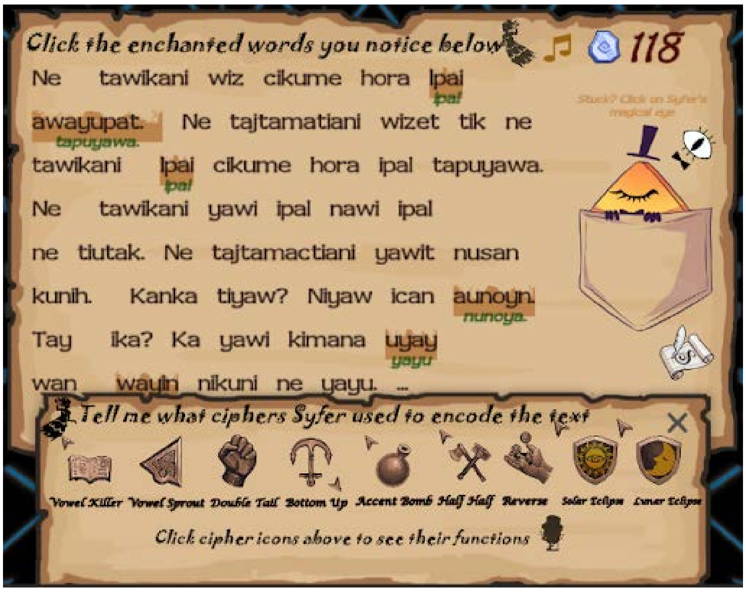


Figure 4.6: A screenshot of the Nawat Cipher game.

Cipher game. This is particularly useful for low-resource languages that are unlikely to have access to high-quality NLP resources for text processing. Figure 4.6 displays a demo screenshot of the Cipher game for Nawat. This shows the interface of the Nawat Cipher game, though the details have not yet been implemented. For demonstration purposes, the interface language is English, but this can be easily reconfigured to Spanish or another language as needed. We anticipate that the methods and the findings from the Irish language adaptation can be applied to other LCTLs in the future.

4.5.2 English for Children with Dyslexia

The Irish Cipher was adapted for dyslexic learners in English by redesigning language learning materials, including vocabulary and reading materials. Adjustments to the game rules were made to reduce text and lower difficulty, addressing the specific needs of dyslexic learners and reducing their anxiety (see Figure 4.7).

Dyslexia-related spells (ciphers), based on common errors made by dyslexic learners, were incorporated to aid in identifying and correcting spelling mistakes and reading errors. Details of dyslexia-related ciphers and their descriptions are

Figure 4.7: A screenshot of the English Cipher game designed for children with dyslexia.

provided in Table 3.4 in Section 3.4.6.1. AI-powered Text-to-Speech technology was integrated to provide clear audio guidance, enabling dyslexic learners to focus on text-based learning targets while reducing the textual demands of gameplay. This adaptation creates a more accessible learning environment, highlighting the potential of advanced technologies to enhance DGBLL experiences. For more details, refer to Section 5.1.3 and Section 5.6.

The game also supports multiple language interfaces, with data stored in Excel sheets for easy adaptation to other languages.

4.6 Addressing Research Question 1

This chapter addressed **RQ1: How can existing game resources designed for dominant languages be repurposed for low-resource languages within the context of CALL?** The adaptation of the Cipher game for Irish learners demonstrates that reusing existing structures can overcome challenges faced by low-resource languages. By reusing key elements from the original English Cipher, the project reduced development complexity and costs in the initial stages, which is critical for proof of concept and the continuation of the research.

The use of the green approach facilitated faster development and the inclusion of culturally relevant Irish content enhanced the game's value as a language learning tool. Positive feedback from primary school students further validated the game's effectiveness, with 73.5% of participants preferring it over traditional learning methods. Additionally, the scalable design of the Cipher Engine allows it to be adapted to other low-resource languages, demonstrating its broader potential.

Several challenges were identified throughout the adaptation, particularly in handling technical limitations and ensuring cultural relevance. Chapter 5 addresses these technological challenges and explores solutions for enhancing DGBLL resources, focusing on how AI and VR can improve adaptability, engagement, and user experience for low-resource languages. Regarding game development iterations, Chapter 4 covers the progression of the game from Stages 0 to 2, while Chapter 5 covers Stages 3 to 5.

Chapter 5

Utilising Advanced Technology in CALL for Low-Resource Languages

5.1 Introduction

References: This section is based on my contribution to (Ward et al., 2024b).

In recent years, with advancements in AI, its role in educational technology has expanded considerably, including in the field of Computer-Assisted Language Learning (CALL) (Tapalova and Zhiyenbayeva, 2022). The intersection of Artificial Intelligence (AI) and CALL holds immense potential to transform language learning experiences. This chapter focuses on the integration of AI into CALL to create a more engaging and supportive educational experience. This section explores the use of Natural Language Processing (NLP), AI image generation and Text-to-Speech (TTS) technologies to enhance the game-like elements of CALL resources. Drawing from experiments conducted at the different stages discussed in Chapter 3, this chapter examines the technical details of the iterative improvements made to the Cipher game, shedding light on the positive impact of AI on both the user experience and learning process. Each iteration is illustrated in Figure 5.1. The integration of NLP, AI image generation and TTS in CALL resources, as exemplified by the Cipher game, demonstrates their effectiveness in creating engaging and inclusive language learning experiences. These technologies not only improve productivity but also cater to the needs of learners with diverse requirements. This research advocates for further exploration and implementation of AI in CALL to promote humanity, interactivity, and accessibility in language education. The following sections (5.1.1, 5.1.2, and 5.1.3) offer a brief overview of each AI technology implemented in the Cipher game. These insights set the stage for a deeper exploration of how NLP, AI-generated images, and TTS technologies are integrated to enhance the language learning experience.

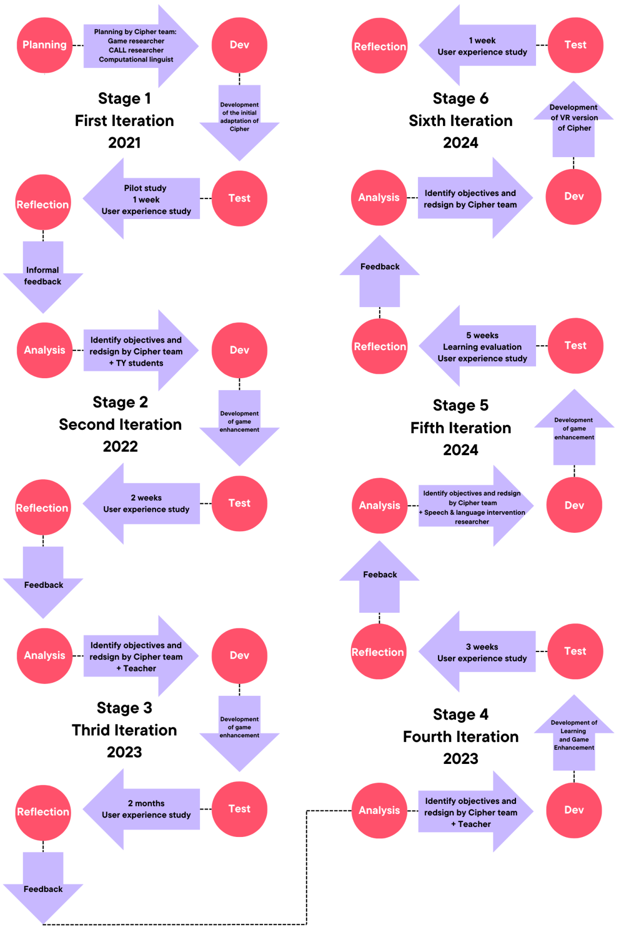


Figure 5.1: Diagram illustrating iterative cycles of Cipher.

In addition, as noted in Chapter 2, VR is an increasingly important technology within the educational sector. One of the primary reasons VR has become popular is its ability to create interactive 3D models that help transform abstract concepts into tangible experiences, thereby enhancing comprehension (Christou, 2010). VR has been shown to be effective for various educational tasks, such as mathematics (Roussou et al., 2006) and language learning (Çakır, 2024; Lan, 2020).

This chapter addresses **RQ2.1: How can AI (i.e., NLP, TTIG, TTS) be utilised to strengthen DGBLL resources for low-resource languages?**

5.1.1 NLP in Cipher

NLP tools are used in several ways in Cipher. NLP tools were used to check for spelling and grammatical correctness, a Part-of-Speech (POS) tagger was used to determine the lexical complexity of the learner texts and a POS tool was used to provide XML formatted POS tagged text to Cipher. It is important to ensure that the texts presented to the players have no spelling or grammatical errors (apart from the spells introduced by the evil spirit) and an NLP tool was used to check for correctness. In CALL resources, it is really important that the language used is at the correct level for the learner (Hashemi and Aziznezhad, 2011). For the most commonly taught language, there are many tools available to check the difficulty of a piece of text (Benjamin, 2012). These tools consider lexical complexity, grammatical complexity, sentence length and other features. In the case of Irish, these tools are not available and there was a need to develop tools to ensure that the texts in Cipher were at the correct level of difficulty for learners. The NLP text level analyser tool for Irish involves lexical analysis, grammatical analysis and frequency analysis. Moreover, the use of Large Language Models for Irish text classification was also investigated (Mc Cahill et al., 2024).

The evil spirit in Cipher can choose which category of words to put under a spell. It is important that certain word categories (e.g., proper nouns) are not put under a spell. A POS tagger for Irish (Uí Dhonnchadha and Van Genabith, 2006) provides XML formatted POS tagged text to the Cipher engine so it can choose to highlight particular parts of speech. This POS information is important for differentiating noun gender in Irish (i.e., masculine and feminine nouns) and it enables the Cipher game to display masculine nouns in blue and feminine nouns in red in the Cipher game. Initially, there were plans to use a POS tagger to analyse texts produced by learners. However, the texts produced by players to get extra points when they ran out of points were at a very basic level and could not be used for this purpose. Some of the texts were in English and others were not full sentences. In order to support learners, later versions of Cipher allowed players to gain points by joining word bricks together to make a sentence in Irish. This word brick approach had been used successfully before (Purgina et al., 2017) and it also worked well in this context. Further details about NLP in Cipher are provided from Section 5.2 to Section 5.4.

5.1.2 TTIG in Cipher

For Text-to-Image Generation (TTIG), we selected MidJourney [1] as the tool for creating visual assets for this project. Among the available alternatives, DALL-E [2] and Stable Diffusion [3], MidJourney stood out due to its ability to produce highly stylised and visually appealing images that cater to creative domains such as art, design, and thematic illustrations (Derevyanko and Zalevska, 2023). Studies have shown that MidJourney is well suited for projects that require artistic imagination, as it excels in generating surreal and high-quality visuals aligned with textual descriptions, especially when incorporating style guides (Derevyanko and Zalevska, 2023).

MidJourney has gained widespread recognition and usage, holding a leading position in search popularity compared to other TTIG models since the public release of version 5 (Wilson, 2023). This popularity underscores its reputation as a reliable and user-friendly tool for creators in various fields, particularly game design (Lee et al., 2023). Furthermore, research has highlighted its utility in both educational and creative contexts Derevyanko and Zalevska (2023).

MidJourney played a crucial role in the Cipher game project. The visual assets

[1] https://www.midjourney.com/
[2] https://openai.com/index/dall-e-2/
[3] https://stablediffusionweb.com/

needed to align with the Irish folklore theme and support an engaging and immersive storytelling experience. Given the scarcity of existing Irish folklore visual references, MidJourney facilitated the realisation of imaginative and culturally relevant visuals. Its ability to allow for iterative refinements, guided by thematic and stylistic constraints, made it an ideal choice Derevyanko and Zalevska (2023); Lee et al. (2023).

Our initial exploration of AI image generation in the Cipher game revealed promising results. Although AI was faster than human efforts in terms of image creation, human intervention and iterative refinement were necessary. Building on this foundation, subsequent developments have integrated AI-generated images into the game, presenting three sequential images per page aligned with the storyline. This evolution not only enhances comprehension but also transforms these images into interactive game components. It was important to ensure that the images were appropriate and consistent. The approach involved using a cartoon-like style rather than aiming for realistic images. The aim was to remain aligned with the overall look and feel of the Cipher game. Examples are shown in Figure 5.2. Additional details about TTIG in Cipher can be found in Section 5.5.

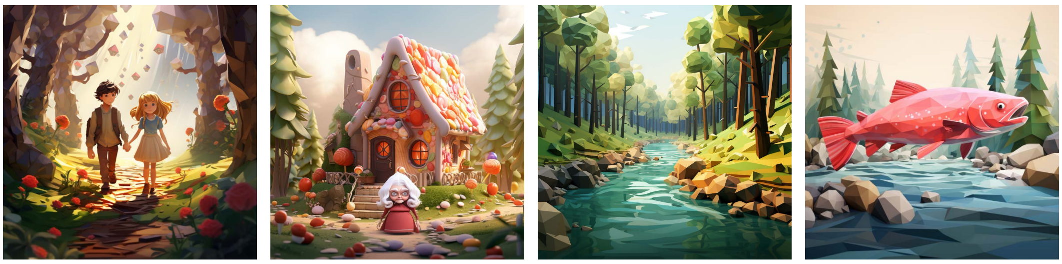


Figure 5.2: Some AI-generated images in Cipher.

5.1.3 TTS in Cipher

A notable addition to the Cipher game is the implementation of TTS AI, designed to assist learners, particularly those with dyslexia. This AI synthesised voice enhances the game's storytelling element and ensures that learners with textual reading difficulties can fully access instructional and motivational game support. While the

Cipher game is designed to be simple and easy to use for learners, sometimes there may be a need to provide extra support. The addition of audio support can help learners play the game independently and not rely on the help of the teacher or another student. In Cipher, TTS systems (e.g., ElevenLabs [4] and ABAIR [5]) are used to convert texts (English and Irish) to clarify game instructions and for language learning. This not only aids in pronunciation and listening but also helps learners with dyslexia understand and play the game on par with others.

ElevenLabs was selected to generate English instructions in the game to facilitate user interaction, particularly for players with language difficulties such as dyslexia. ElevenLabs is a state-of-the-art TTS platform known for its realistic and expressive voice synthesis capabilities (Nițu, 2024). Research has shown that it has been successfully applied across various domains, including education (e.g., language learning (Xu, 2024; Zulaiha et al., 2024)), games (e.g., enhancing player immersion (Nițu, 2024)) and VR (e.g., audio narration (Sunder, 2024)). A survey conducted by Sunder (2024) demonstrated that ElevenLabs was preferred for audio narration over other TTS platforms such as Murf [6], Speechify [7], and PlayHT [8] in the context of VR development, due to the quality and dynamics of its voice outputs. Furthermore, ElevenLabs showed an advantage in supporting multilingual and immersive applications (Nițu, 2024), which further validates its selection for this research. These findings align with the objectives of this study, where the tool's ability to provide high-quality and natural audio guidance can facilitate smoother interaction for diverse user groups.

In the game's context, voice characteristics need to be tailored to match the thematic elements, contributing to a cohesive and immersive player experience. Other considerations such as cost-efficiency, ease of integration, and the tool's proven ability to meet the dynamic and flexible requirements of the project were key factors in the

[4] https://elevenlabs.io/
[5] https://abair.ie/ga
[6] https://murf.ai/
[7] https://speechify.com/
[8] https://play.ht/

decision to adopt ElevenLabs after comparing to other state-of-the-art options such as Goolge TTS [9], IBM Watson [10] and Microsoft Azure TTS [11].

TTS was also used to support the vocabulary learning element of Cipher. ABAIR is a TTS tool specifically designed for Irish and can generate audio files in three different dialects of Irish and at different speeds. The choice of ABAIR as the Irish TTS technology for this study stems not only from its suitability for the Irish language but also from the limited availability of resources for Irish. Furthermore, ABAIR demonstrated effectiveness in existing Irish CALL applications. Prior research has validated the utility of ABAIR in CALL. For instance, Digichaint (Ní Chiaráin and Ní Chasaide, 2016b) and two additional CALL applications (Ní Chiaráin and Ní Chasaide, 2015, 2016a) developed by the same research group, employed ABAIR and revealed positive learner reception in terms of intelligibility, quality, and attractiveness of the synthetic voices.

ABAIR was used to generate the audio files for each of the Irish vocabulary words in Cipher. Irish orthography is not transparent and it can be difficult for learners to decipher the correct pronunciation of Irish words (Hickey and Stenson, 2011). It is essential for learners to know how to pronounce words correctly as part of the language acquisition process. Further details about TTS in Cipher are provided in Section 5.6.

5.1.4 VR for Cipher

As noted in Chapter 4, traditional language learning methods often fall short in engaging learners, especially in the context of indigenous languages like Irish. Moreover, as discussed in Chapter 2, there are complex social and cultural factors. The limited daily use of Irish outside educational settings, combined with outdated teaching methods and a lack of interactive resources, contribute to student disengagement. These issues are compounded by social and cultural perceptions of

[9] https://cloud.google.com/text-to-speech
[10] https://www.ibm.com/watson
[11] https://azure.microsoft.com/en-us/products/ai-services/ai-speech

Irish as less essential compared to global languages, influencing motivation negatively. Effective engagement requires easing these barriers and refreshing teaching approaches with relevant, dynamic content that connects learners with the culture of the language in a fun and engaging manner (Lan, 2021).

Cipher: Faoi Gheasa harnesses the power of Digital Game-Based Language Learning (DGBLL) to address these challenges. Initially designed for English, Cipher has undergone several iterations to adapt to the Irish context and is now completing its metamorphosis into a VR platform aimed at supporting less-resourced and minoritised languages. In Cipher VR, players immerse themselves in a magical world, engaging with language learning tasks enriched by fairytale and folklore elements, making the process both interactive and captivating. Cipher VR integrates VR to deepen immersion in indigenous culture, aiming to amplify cultural contexts, bringing them to the forefront of language learning as a means of enhancing learner motivation. Further details on these methodologies are provided in Section 7.2. Chapter 7 focuses on strengthening the cultural relevance of the CALL environment in VR, exploring how reconnecting with cultural roots through immersive technology can deepen language learning experiences.

5.2 Game and NLP

During the process of adapting Cipher from English to Irish, NLP resources and tools have contributed in different ways to the development of Cipher: Faoi Gheasa. For example, Part-of-Speech (POS) tagging is used for text difficulty analysis, cipher detection analysis, and the analysis of player-written texts in learner corpus collection.

5.2.1 Pre-Processing

There were three main sources of texts for Cipher: Faoi Gheasa:

- international fairytales.

- texts from the Gutenberg Project [12].
- Dúchas [13] texts which include original texts based on traditional Irish stories).

The selected Dúchas texts were stories written by children in the 1930s. Further details on Dúchas texts are provided in Section 7.1. These texts were not written in the Official Standard for Irish (An Caighdeán Oifigiúil [14]) and needed to be converted to the modern standard. Texts were manually converted and an Irish POS tagger was used to check for further spelling combinations that needed to be updated. In addition, some of the older texts used the Gaelic font, for example, ċ needed to be replaced by ch. Once these changes had been made, all texts were reviewed for errors using the online electronic version of Ó Dónaill's Irish-English Dictionary [15] and Gramadóir [16] spelling and grammar checker for Irish. Figure 5.3 to the left shows this pre-processing step.

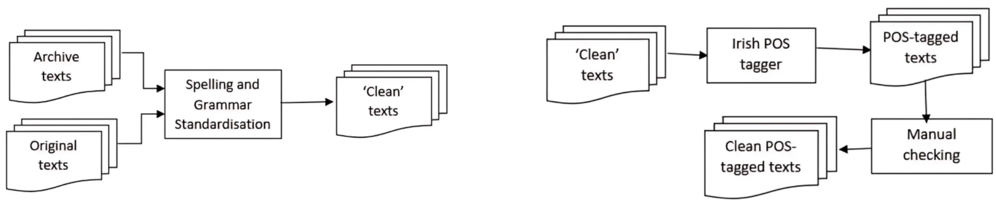


Figure 5.3: Pre-processing (left) and POS tagging (right).

5.2.2 POS tagging

The Irish POS tagger (Uí Dhonnchadha and Van Genabith, 2006) uses Parole morpho-syntactic tags (Monachini and Calzolari, 1999) and the XML Corpus Encoding Standard (Ide et al., 2000). The tagging is done in three stages: tokenisation, morphological analysis of tokens and part-of-speech disambiguation of the morphological analyses. The tokenisation and morphological analysis are done

[12] https://www.gutenberg.org/browse/languages/ga
[13] https://www.duchas.ie/
[14] https://data.oireachtas.ie/ie/oireachtas/caighdeanOifigiul/2017/2017-08-03_an-caighdean-oifigiuil-2017_en.pdf
[15] https://www.teanglann.ie/en/fgb/
[16] https://cadhan.com/gramadoir/foirm-en.html

using finite-state transducers based on Beesley and Karttunen (2003)'s morphological approach. Text can be segmented into tokens largely based on white space, with exceptions for multi-word items and the separation of contracted forms which join two words. The morphological analysis produces a number of possible analyses for each token. Constraint Grammar (Bick and Didriksen, 2015; Tapanainen, 1996) rules are used to choose the correct analysis based on the context. Irish has a rich inflectional morphology and a rule-based approach is used throughout for the POS tagging, chunking and parsing tools.

The POS tagger for Irish provides XML formatted POS tagged text to the Cipher engine so it can choose to focus on particular parts of speech. The tagger which was initially developed for general Irish texts, can provide useful information for educational purposes as well. Figure 5.3 to the right shows the POS-tagging step.

Noun gender is important when learning Irish vocabulary, but it is rarely taught explicitly in schools and students are often unaware of the concept of gender in Irish. Most Irish language learners in Ireland are L1 English speakers and they are unfamiliar with the concept of grammatical gender. In Cipher: Faoi Gheasa, we draw attention to the gender of nouns by highlighting masculine and feminine nouns in different colours.

For example, the word *laoch* 'warrior', a masculine noun would be highlighted in sapphire blue (representing the colour of the Water Spirit) and the word *murúch* 'mermaid', a feminine noun would be highlighted in ruby red (representing the colour of the Fire Spirit). As noted in Chapter 3, gender highlighting in the context of the game fits into the game storyline. Figure 5.4 shows a page of a story where all masculine nouns (e.g., *lá* 'day' and ocras 'hunger') are coloured blue while the feminine nouns (*tine*, 'fire' and cailleach 'witch') are coloured red. The names 'Hansel' and 'Gretel' are also coloured according to their gender but words tagged as proper nouns by the POS tagger are excluded from ciphers as there is variability in the ways in which names are spelt and it can be difficult to determine whether a cipher has been applied or not. For illustration purposes, the ciphers and their correct forms are shown in Figure 5.4.

Figure 5.4: Cipher screen with ciphers and word gender highlighted.

Normally, when a player is playing the game, the correct forms are not shown (see Figure 5.5) unless power-ups (e.g., 'Evil Eye', see Figure 5.6) are used. Cipher: Faoi Gheasa also has an Irish language interface but the English language version is shown here for illustration purposes. The Cipher engine can be easily reconfigured to focus on different aspects of language as desired, e.g., noun plurals or particular verb tenses.

Figure 5.5: Cipher screen with ciphers and word gender highlighted.

Figure 5.6: The power-up 'Evil Eye'.

5.2.3 Text Level Analyser

As noted in Chapter 2, Vygotsky (1978)'s Zone of Proximal Development (ZPD) is a crucial concept in learning theory and is particularly relevant in language learning contexts. In the Cipher game, ensuring that learners are presented with texts matching their language ability is essential for maintaining engagement and motivation. Texts that are too challenging can lead to frustration and demotivation, while overly simple texts can result in boredom and disengagement. A text that has a level of linguistic difficulty that is suitable for the learner will be more engaging for them and will incentivise them to play the game. To address this, Cipher employs a combination of text analysis and NLP tools to determine the linguistic complexity of texts. There are several checkers available for this in English e.g., Flesch–Kincaid readability tests (Kincaid, 1975). There are currently no publicly available text analysis tools for Irish, however the Irish NLP tools [17] are used to provide information about lexical and grammatical complexity which is used to rank the Irish texts used in Cipher: Faoi Gheasa. Figure 5.7 shows the steps in the lexical analysis process. Furthermore, the text classification process is semi-automated by utilising the detailed text analysis results as a baseline (see Section 5.3). Building on this robust baseline, machine learning and neural-based text classifiers were tested and showed promising results and good potential (see Section 5.4).

[17] https://www.scss.tcd.ie/óÃ̃ìuidhonne/irish.utf8.htm

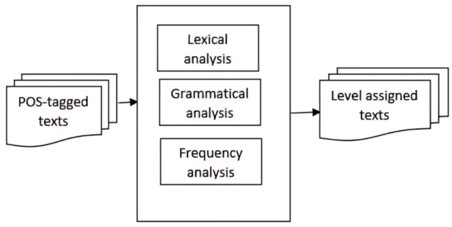


Figure 5.7: Level analysis phase.

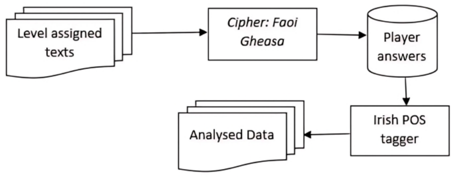


Figure 5.8: Analysis of cipher detection phase.

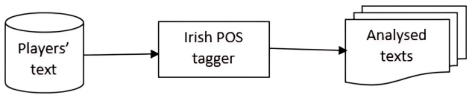


Figure 5.9: Analysis of player texts phase.

5.2.4 Analysis Cipher Detection

As players engage with Cipher: Faoi Gheasa, their gameplay metrics are captured in real time and stored in a relational database (see Section 4.2.1) on the server for later comprehensive analysis. To gain deeper insights into the players' knowledge and awareness of Irish spelling, the Irish POS tagger is employed to annotate this data. This process helps to evaluate the players' proficiency and learning progress in real time. Figure 5.8 illustrates the steps involved in analysing the cipher detection phase. For instance, during the reading task, the analysis can focus on four key metrics:

- Cipher words correctly identified by players (true positives)
- Cipher words missed by players (false positives)
- Normal words incorrectly identified by players (false negatives)
- Normal words correctly identified by players (true negatives)

This detailed analysis, combined with other gameplay data (e.g., time spent reading a story), will contribute to the development of a stealth assessment framework in future work, enabling a more nuanced evaluation of language learning progress without interrupting the gameplay experience.

5.2.5 Analysis of Player Texts and Learner Corpus Collection

If players fail to identify a sufficient number of ciphers on a page of text, they have the option of entering a sentence to change the ending of the story, allowing them to replay the game. The sentences entered in this way can be analysed to provide further insight into the players' understanding of the text they have read and to give some insight into their level of Irish. Figure 5.9 shows the analysis phase of players' texts. The sentences entered by the players can be collated to form a corpus of learner Irish. Currently, there is no such publicly available learner corpus from a game for Irish. The use of Cipher: Faoi Gheasa could facilitate the development of such a corpus. For instance, future research could explore the potential of using an online game in which participants compose sentences and consent to their data being stored, enabling the systematic collection of learner-generated language content.

However, the initial feature of collecting text from users in Cipher has later been replaced by the 'word brick' feature (see Figure 5.10), as explained in Section 3.4.5.1. Consequently, the components of the project dedicated to the analysis of player texts and learner corpus collection are no longer active. This updated feature allows players to construct sentences from predefined blocks, which has proven to be more effective in supporting learners and facilitating gameplay.

5.2.6 NLP Pipeline

The NLP pipeline architecture can help to build other versions of Cipher that are language-specific and culture-specific. The game will work in the same way but can be customised for different languages. Figure 5.11 provides an overview of the NLP pipeline for Cipher: Faoi Gheasa. It shows the role of each NLP component in the creation of Cipher: Faoi Gheasa and the subsequent analysis of the players' actions while playing the game.

Figure 5.10: Writing feature update.

5.3 Text Analysis for Adaptive Learning

References: This section is based on my contribution to (Uí Dhonnchadha et al., 2024).

In this section, we explore the adaptive learning feature of Cipher, with a focus on the use of text analysis for difficulty adjustment. By integrating text analysis techniques, Cipher has the potential to dynamically adjust its difficulty based on the player's progress and language proficiency, offering a customised learning experience.

Xia et al. (2019) note that while most studies of text readability are carried out

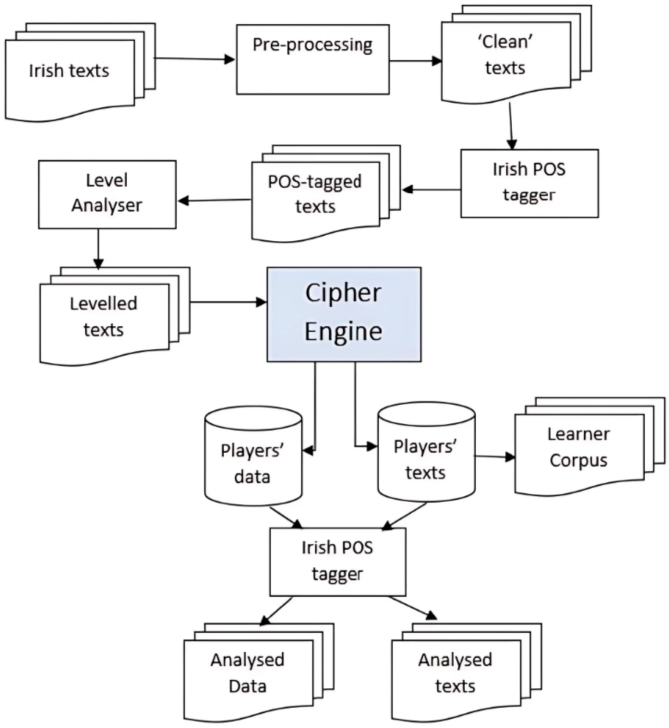


Figure 5.11: Writing feature update.

by native speakers, L2 learners can perceive text comprehensibility very differently. Therefore, a system such as Cipher that adapts to the L2 learner's perception of text difficulty based on their performance in the game will better facilitate language learning.

In order to provide texts of an appropriate level for adaptive learning, it is necessary to be able to classify texts according to their relative complexity. In relation to second language acquisition, Michel (2017) notes that language complexity can be defined in a number of ways. It can be thought of as a) developmental complexity, i.e., the order in which linguistic structures are typically acquired, b) cognitive complexity, the subjective difficulty of a language feature from the perspective of the learner and c) linguistic complexity, i.e., objective complexity of linguistics forms (e.g. morphological forms and syntactic constructions) and meanings and form-meaning mappings (Michel, 2017). In this section, we focus on linguistic complexity and the features that can be used to determine the complexity of a text. In the literature, a wide variety of measures have been used to calculate linguistic complexity using a combination of lexical, grammatical and discourse features.

Regarding lexical measures, (Lu, 2012) describes lexical richness as a combination of lexical density (ratio of content words to total words), lexical variation or diversity (ratio of different words to total words) and lexical sophistication (proportion of advanced or sophisticated words in a text, using frequency lists or specialised word lists). A summary of lexical measures is provided in Table 5.1. Lexical familiarity/unfamiliarity (Collins-Thompson, 2014) is a similar concept to lexical sophistication as it is also measured using frequency lists derived from relevant corpora, i.e., words are assumed to be familiar to a reader if they occur frequently words in a relevant corpus, and conversely they are considered unfamiliar or sophisticated if they appear frequently in a relevant corpus. Grammatical complexity can be characterised in terms of syntactic variation and sophistication, and most measures are based on the mean length of sentence/utterance or on structural analysis (Lu, 2010; Vajjala, 2021). Discourse measures of text quality include text cohesion, discourse relations and entity chaining (Feng et al., 2010; Pitler and Nenkova, 2008). Measures of discourse complexity associated with comprehension difficulty include propositional idea density (Brown et al., 2008; Feng et al., 2010). A text with greater propositional density is more difficult to comprehend than a text with lower propositional density. In this measure, predicates (e.g., verbs) modifiers (adjectives, adverbs, qualifiers) and conjunctions are considered to be indicative of propositions.

Measure	**Definition**
Lexical density	Ratio of content words to total words
Lexical variation or diversity	Ratio of different words to total words
Lexical sophistication	Proportion of advanced or sophisticated words in a text using frequency lists or specialised word lists

Table 5.1: Lexical richness as a combination of density, diversity and sophistication

5.3.1 Reading and Readability Measures

References: This subsection is based on my contribution to (Uí Dhonnchadha et al., 2022).

Reading is widely acknowledged to be an effective way to increase vocabulary and, for L2 language learners, it is a particularly important way to gain exposure to grammatical structures (Heilman et al., 2007; Uí Dhonnchadha et al., 2022). Reading practice is a vital component of first and second language learning, particularly for vocabulary learning (Heilman et al., 2008). Matching the level of the text with the language proficiency of the learner is particularly important. Harris et al. (1996) suggest that language input needs to be challenging to provide opportunities for learning, and they caution against over-simplification of written texts, which can result in stories that are bland and unnatural. They note that there is scope for using more complex language in the context of stories which are already familiar to the learners. For the beginner levels, we use well-known fairy tales such as 'Goldilocks and the Three Bears' and 'Hansel and Gretel', which will be familiar in the learner's first language (L1), followed by less well-known folktales and myths that are presented as they progress through the levels in the game.

However, choosing reading material of an appropriate level for the learner is a complex task which needs to take several factors into account, including both reading ability and reading interests. Both readability and complexity measures have been used in attempts to match the reading materials with the level of proficiency of the learner. Readability measures tend to focus on text and its characteristics, while complexity measures focus on language learner output (Vajjala and Meurers, 2012). Commonly used text-based readability measures include average sentence length, average word length in characters or syllables (Flesch, 1948; Kincaid, 1975), and word frequency lists (Dale and Chall, 1948). Below are brief definitions of commonly used readability measures:

- Flesch Reading Ease: This measure evaluates text readability based on the average sentence length and the average number of syllables per word, with higher scores indicating simpler texts Flesch (1948).

- Flesch-Kincaid Grade Level: An extension of the Flesch Reading Ease, this metric translates the readability score into a US school grade level, facilitating the alignment of text complexity with educational standards (Kincaid, 1975).
- Dale-Chall Formula: This formula combines the average sentence length with the percentage of difficult words not on a standard list of 3,000 familiar words (Dale and Chall, 1948).

Discourse features and text cohesion are also used in some readability measures (Graesser et al., 2014). Complexity measures which focus more on the learner's capabilities tend to measure lexical diversity, number and types of clause per sentence or other unit, and other features such as verb tense, mood, voice, etc. Vajjala and Meurers (2012) maintain that both types of measure are important for choosing appropriate learning materials. Of the lexical and syntactic measures they implemented for English, they found type/token ratios, verb variation, modifier variation, and number of characters/syllables per word to be among the most useful lexical measures. Mean length of clause, as well as the number of co-ordinate phrases and complex nominals per clause, were among the most useful syntactic measures. See Vajjala and Meurers (2012) for a survey of recent research on automatic readability assessment. Gutierrez-Vasques and Mijangos (2018) discuss measures of morphological complexity measures. This topic is of relevance to languages such as Irish which encode substantial semantic and grammatical information in their inflectional paradigms.

Ó Meachair (2019) investigated a range of complexity metrics for Irish educational materials using the EduGA corpus compiled for this purpose. These measures include (a) a comparative frequency of prescribed lexicogrammatical features, (b) an analysis of sentence and word length, and (c) an analysis of terminology topicality. Of particular interest to our research are the sentence and word length metrics. He found that sentences in lower-level Irish educational materials contained fewer words on average than sentences in higher-level materials, indicating that this metric behaves as an indicator of increasing complexity for Irish educational materials. This finding is in line with results for other languages. However, he found that increases in average word length did not correlate with increases in educational materials level, and average word lengths fluctuated significantly across all subcorpora.

Hickey (2007) discusses the importance of developing fast, accurate, word recognition skills in young readers, which facilitates satisfying independent reading. She echoes Gardner (2004)'s view that "high-frequency words must be mastered in order to achieve minimum levels of reading proficiency in both L1 and L2". She analyses a list of the 100 most frequent words in a corpus of Early Reader books (18K words) for 7-13 years and suggests ways of teaching the most frequent words.

5.3.2 Text Analysis for Irish

A DBGLL application that relies on target language texts also needs to be able to use texts of the appropriate level for individual learners. This implies that text analysis techniques should be available to DGBLL developers, who may not be familiar with the target language, in order to incorporate suitable texts into their games. While text difficulty classifiers exist for many of the most commonly spoken languages, this is not the case for under-resourced languages.

Much of the research to date on text analysis and complexity measures has focused on languages such as English (Vajjala and Meurers, 2012) while under-resourced languages such as Irish have not been researched to the same extent. In this section, we calculate lexical, grammatical and discourse features. Due to the small amount of pre-graded material available for an under-resourced language such as Irish, we choose to do a detailed linguistic analysis of the available material. This will satisfy our immediate need for grading texts for Cipher as well and help to generate graded material for machine learning methods.

We calculate lexical density as the ratio of content words to total words, lexical diversity as corrected type-token ratio, and for grammatical complexity we use average sentence length, following findings for Irish in Ó Meachair (2019) and Uí Dhonnchadha et al. (2022). Although more complicated syntactic measures can be used, in children's literature in particular, longer sentences are a good indicator of greater complexity, i.e., there are more modifiers, or subordinator relative clauses (Lan et al., 2019).

As noted in Pitler and Nenkova (2008), the vocabulary used in a text largely determines its readability. Therefore, we determine lexical sophistication (or familiarity) as the percentage of words that are among the n most frequent in a range of frequency bands using frequency word lists which are based on lists in Breacadh (2007).

As regards discourse, since we are interested in reading comprehension difficulty rather than assessing text quality we investigate propositional idea density where a propositional idea is indicated by a verb and its arguments, a copula and its arguments or an adverbial phrase, as described in (Brown et al., 2008).

5.3.3 Data and Methodology

We carry out a detailed analysis of pre-graded reading materials to develop predictive measures for ungraded material, i.e., to grade new stories for use in the Cipher game.

5.3.3.1 Data selection and preparation

Two sets of graded materials are used: Taisce Tuisceana [18] (TT), a collection of Irish reading comprehension texts for primary school students and Séideán Sí [19] (SS) a series of textbooks for Gaeltacht and Gaelscoileanna – Irish-medium primary schools in Ireland.

For initial exploration, we use ten samples of fiction from Taisce Tuisceana (TT). These texts are graded [20] from A to E with A-C for Key Stage 1 (1st and 2nd class) and D-E for Key Stage 2 (3rd and 4th class). For increased robustness, we asked 5

[18] `https://ccea.org.uk/learning-resources/taisce-tuisceana`
[19] `https://seideansi.ie/`
[20] Graded A for 1st & 2nd class, B & C for 3rd and 4th class and D & E for 5th and 6th class on `www.tairseachcogg.ie`

Irish speakers who studied Irish to secondary school level in Ireland to rank the texts in order of increasing difficulty based on their intuition, and we took the average of these ratings. While there was some variation within categories, there was very little variation between the categories, as shown in Table 5.2, which provided added confidence in the ranking.

Taisce Tuisceana	**Cat.**	**Class**	**R1**	**R2**	**R3**	**R4**	**R5**	**Ave Rank**	**StDev**
A06	A	1st, 2nd	1	1	1	1	1	1.00	0.00
B22	B	1st, 2nd	3	3	2	2	5	2.20	0.45
B20	B	1st, 2nd	2	5	4	5	6	4.00	1.58
C23	C	1st, 2nd	5	3	3	3	4	4.60	1.41
C08	C	1st, 2nd	4	4	5	5	5	4.60	0.55
D05	D	3rd, 4th	7	6	4	6	7	5.40	1.34
D08	D	3rd, 4th	4	8	7	7	8	6.80	0.84
D21	D	3rd, 4th	8	7	9	9	8	8.20	0.84
D22	D	3rd, 4th	9	9	8	9	9	9.00	0.71
E02	E	3rd, 4th	10	10	10	10	10	9.60	0.89

Table 5.2: Taisce Tuisceana texts and grading. (R1–R5 are Raters 1-5, the 5 Irish speakers)

The second dataset, Séideán Sí (SS), is larger and more comprehensive. See Table 5.3. It consists of textbooks which are pre-graded for primary school students from first class (ages 6-7) to sixth class (ages 11-12). From this collection we selected all samples of fiction (86), 10% of which (8 files) were set aside for testing and the rest were used to develop grading measures.

Stage	**Class**	**Age**	**Files**	**Words**
Keystage 1 (6-8 years)	1st Class	7-8	30	5721
	2nd Class	8-9	24	15679
Keystage 2 (8-11 years)	3rd Class	9-10	6	15539
	4th Class	10-11	10	23585
	5th Class	11-12	9	28894
	6th Class	12-13	7	40793
TOTAL			86	130211

Table 5.3: Séideán Sí texts

The PDF files which were converted to text and cleaned, were then part-of-speech (POS) tagged and lemmatised using existing tools for Irish. This rule-based POS tagger achieved an average accuracy of 97% on a random selection of eight Séideán Sí texts covering all levels. Along with these stories, a 10K frequency wordlist was extracted from the fiction part (6 million words approx.) of the New Corpus of Ireland [21] (NCI). The NCI corpus consists of 30 million words of Irish, of which 6 million words are labelled as fiction in the metadata.

5.3.3.2 Calculation of Text Statistics

Text statistics were obtained for each story using Python programmes which process each POS-tagged file to get the required lexical, grammatical and frequency measures (Bruen and Uí Dhonnchadha, 2024).

For the lexical measures, TTR (type token ratio), WTR (word type ratio) and CTTR (corrected type token ratio) were calculated by using formulae in (Lu, 2012; Vajjala and Meurers, 2012). For the grammatical measure, WDSEN (average number of words per sentence) was calculated along with various other text statistics as shown in Table 5.4. For word familiarity (sophistication) measures, we compared the word types in each text with the frequency wordlist and calculated the number of words that were within frequency ranges 0-100, 100-300, 300-500, 500-1000, 1000-2000, 2000-3000, 3000-4000, 4000- 5000, 10000+. These frequency ranges are used because these are the wordlists that were compiled by Breacadh (2007) specifically for children's texts. Each story was labelled based on its year group in the original dataset e.g., first class stories were labelled '01_' followed by the story name while sixth class stories were labelled '06_' followed by the story name.

Finally, propositional idea density was calculated using POS tags for verbs, copula, adjectives, adverbs and conjunctions.

Feature Counter

The first tool (feature counter) calculates text statistics such as number of sentences, tokens, types, words, lemmas, longest sentence, and POS totals (using the first

[21] https://corpas.focloir.ie

two characters of the PAROLE5 POS tag e.g., Noun-proper (Np), Verb-main (Vm), Pronoun-personal (Pp), Noun-verbal (Nv), Pr (Pronoun-prepositional), etc. and nouns with genitive case. Table 5.4 gives an example of the output from this tool.

FILENAME	**sen_count**	**tokens**	**types**	**word_count**	**ave_sen_len**	**lemtypes**	**gen_count**	**Np**	**Pr**	**Av**
01_C1_Am	13	109	48	90	6.92307692	40	3	2	6	0

Table 5.4: Output from the Feature counter tool

Lexical and Grammatical Calculator

The second tool calculates lexical and grammatical measures for the files. These measures were Type Token Ratio (TTR), Word Type Ratio (WTR), Corrected Type Token Ratio (CTTR) and Words per Sentence (WDSEN). Table 5.5 gives an example of the output from this tool.

FILENAME	**TTR**	**WTR**	**CTTR**	**WDSEN**
01_C1_Am	0.533333	1.875	3.577709	6.923077

Table 5.5: Output from the Lexical and Grammatical calculator tool

Frequency Range Tool

The third tool calculates the frequency measures for each file by using a wordlist of the 10,000 most frequently used words in Irish fiction. For every word in each file, if the word was within the frequency list, the appropriate frequency range was incremented, otherwise the 10K+ range was incremented. Table 5.6 gives an example of the output from this tool, showing that 24 word types are in the 100 most frequent words (100FREQ), 9 word types are between 101 and 300 frequency, and so on.

FILENAME	**TYPES**	**100FREQ**	**300FREQ**	**500FREQ**	**1000FREQ**	**2000FREQ**	**3000FREQ**	**4000FREQ**	**5000FREQ**	**10kplusFREQ**
01_C1_Am	49	24	9	2	2	2	3	2	1	3

Table 5.6: Output from the Frequency tool

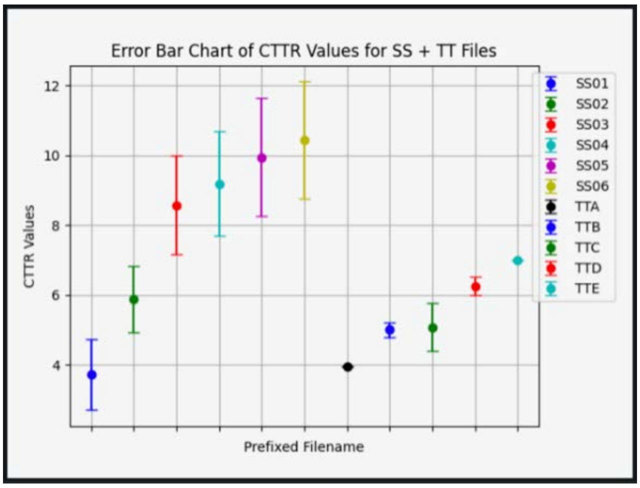


Figure 5.12: CTTR values for SS, TT text.

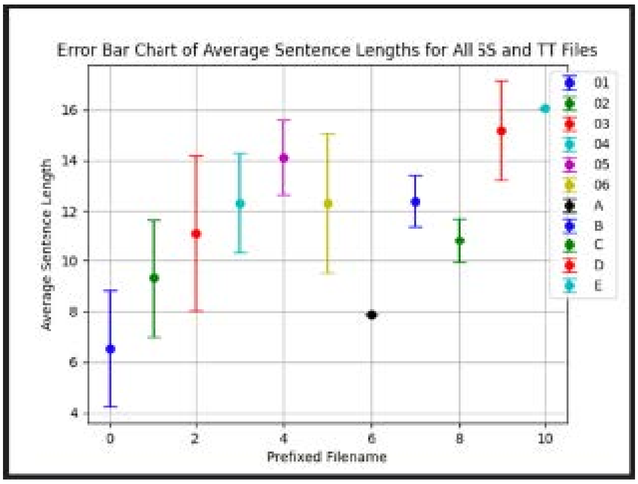


Figure 5.13: Average sentence length values for SS (01-06) and TT(A-E) files.

5.3.4 Text Analysis Results

Graphs were used to visualise the results. CTTR and average sentence length prove to be the most predictive measures, showing increasing values for first to sixth class texts. Figure 5.12 shows the range of CTTR values for Séideán Sí (SS) files (labels 01 – 06), and Taisce Tuisceana (TT) files (labels A – E). Figure 5.13 shows the average sentence length for SS and TT files.

Figures 5.14 and 5.15 show each SS and TT text groups and their percent of types in each frequency range from 0-100 to 10K+. In this Zipf-like curve the proportion of words in the 1-100 frequency range appears to be the most useful frequency range for predicting text level.

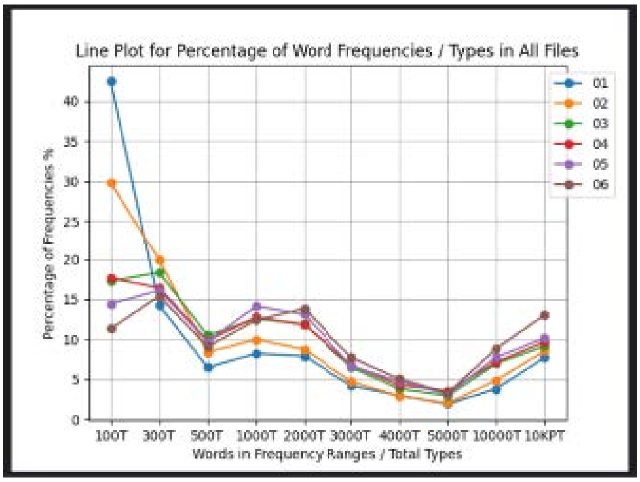


Figure 5.14: Type/Frequency ranges of SS texts.

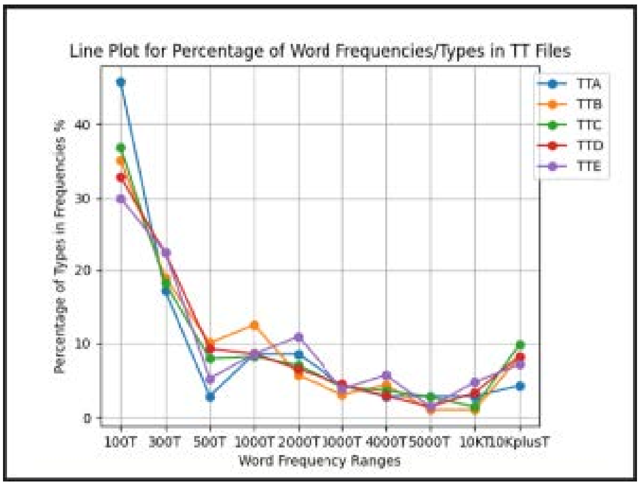


Figure 5.15: Type/Frequency ranges of TT texts.

The graphs show that the measures of CTTR, average sentence length and frequency for the pre graded texts are behaving as one would expect, with an increase from first class texts to sixth class texts.

In Figure 5.12, we see that the TT files fall within the range of SS 1st to 3rd class (01-03). In Figure 5.13, the average sentence length for TT files falls within the range of 1st to 6th class and higher. It is also apparent that higher-level texts do not always have a greater average sentence length, as can be seen from 05 and 06 texts as well as B and C texts. This suggests that a composite measure is required as there is often a trade-off between lexical complexity and grammatical complexity (Graesser and McNamara, 2011).

By plotting ungraded texts alongside these graded texts, we can infer a grading for the texts based on where they are in the plots in relation to the SS and TT files.

In Figure 5.16, we show CTTR for six ungraded Cipher Texts (CT) in comparison to the SS texts, and in Figure 5.17, we show average sentence length for the same six ungraded Cipher Texts (CT) in comparison to the SS texts.

The Cipher texts comprise two Irish mythology texts (CTX12, CTX14), two Dúchas Irish folklore texts (CTX21, CTX22) and two international fairy tales (CTX33, CTX34).

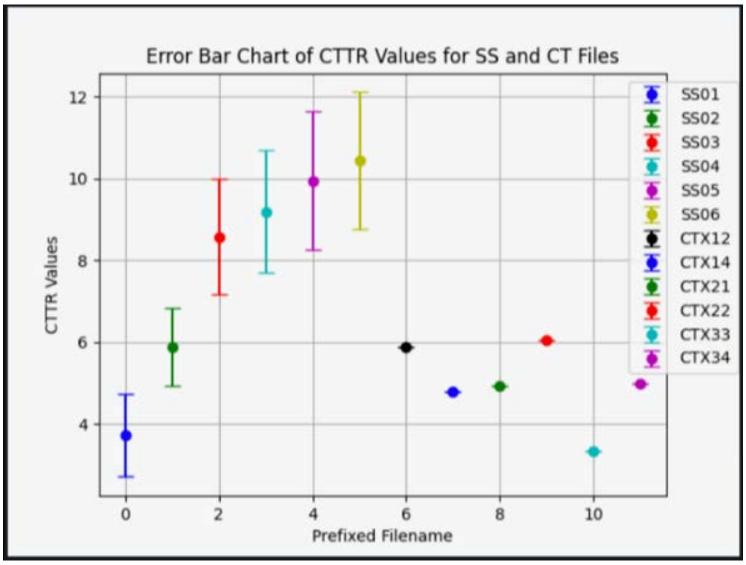


Figure 5.16: CTTR for SS and ungraded Cipher Texts (CT).

As we can see from Figures 5.16 and 5.17 the mythology texts (CTX12, CTX14), fall within the 2nd and 3rd class range, the Dúchas texts (CTX21, CTX22) are lexically in the 2nd class range but are in the 5th and 6th range and above in terms of sentence length, while the fairy tales are in the 1st and 2nd class ranges. These results are as expected. In particular, the results for the Dúchas texts are interesting, given that these texts were written by 5th- and 6th-class children in the 1930s as

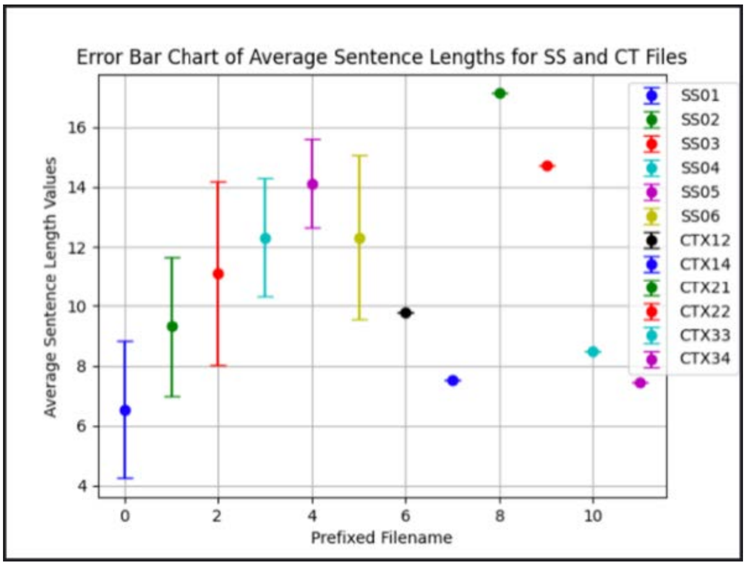


Figure 5.17: Average sentence length values for SS and ungraded Cipher Texts (CT).

part of the Irish Schools Collection (Ó Cleircín et al., 2014).

5.3.5 Composite predictive measures

These visual results are useful, but we need to be able to automatically assign a grade in the range 1-6 to ungraded texts. Predicting the grade level of ungraded texts was carried out in an incremental manner. We began with one feature, CTTR. From our pre-graded SS texts (Figure 5.12), we could estimate value ranges for this measure for each age group. For example, we could see the majority of the *first class* files had a CTTR value between 1 and 4, so we set our first range to be 1 to 4, while range 2 which correlated with *second class* was 4 to 7.6, range 3 for *third* class was 7.6 to 8.6, range 4 for *fourth class* was 8.6 to 9.5, range 5 for *fifth class* was 9.5 to 13.5 and range 6 for *sixth class* was 13.5 plus. With every file, the CTTR value was compared with these ranges and when a value landed in a particular range, that range number (1 to 6) was returned to give the CTTRRangeValue. From using this measure alone, we could see there were multiple outliers in each age group that were giving a higher range value than expected so to help account for those outliers, the WDSEN measures was added.

The same principles were followed for this measure by having different ranges for this measure. With these two measures, an average was taken from the CTTRRangeValue and WDSENRangeValue to give a rounded predicted grade level. The predicted grade level was still not overly accurate for all six grade levels. Therefore the measure '100T' was added to the calculation following the same format and having its own range values. This measure calculates the percentage of types in a file that are within the first one hundred words of our frequent word list. The TypeRangeValue was added with the two other range values to get an overall average which still was unsatisfactory, leading to the addition of the lemma type count to the calculation. A set of ranges were set for lemma types and the value was added to the previous three features.

The average of the four measures shown in Table 5.7 gave a more satisfactory result, with 60% of the predictions being exactly right, and 34.1% of the predictions being out by one grade level. This is a good result with over 90% predictions being correct or within one grade of the correct grade. See Table 5.7 for details.

Feature	**Exact match**	**Within 1 grade level**
CTTR	58.76%	31.2%
+WDSEN	55.29%	36.4%
+100T'	59.4%	30.58%
+Lemma types	60.0%	34.12%

Table 5.7: Initial grade prediction results

There are approximately 80 SS files, and 10% (8 files) were randomly selected and set aside as held-out data to test this formula on unseen texts. These held-out files were used to check accuracy levels. Among the 8 files, 70% of the predictions were exactly correct, while 30% of the predictions were off by one grade level. See Table 5.8 for details. The predictive grading measure is used to assign a grade to the ungraded Cipher texts. These results are in keeping with the visual results in Figures 5.15 and 5.16 and with the team members' expectations. The Dúchas texts (CTX21, CTX22) are predicted to be suitable for 3rd and 4th grade which reflects a combination of 2nd grade lexical features and 5th and 6th grade sentence length.

Held out SS Text	Predicted Grade	Actual Grade
IgCéiniseigCóngar.txt	5	6
AnMúinteoirNua.txt	4	3
Céhiadseo.txt	1	1
AnNathairagusnaSpléaclaí.txt	3	3
SinScéalEile.txt	5	5
MurachanTraenáil.txt	2	2
SciobAgusAnChuileog.txt	1	1
AChaitlínMí-abha.txt	3	3

Table 5.8: Grade predictions for held out SS texts

These automatic grading results are promising and we intend to verify them by carrying out more extensive testing on unseen, manually graded texts.

A limitation of this study is the small sample size. In addition, we limited our study to only fiction texts. Therefore, it is unclear how well the predictions would generalise to other types of text.

5.3.6 Text Analysis Summary

The integration of Irish culture and mythology not only enhances engagement and motivation but also fosters a deeper connection with the language. Findings suggest that such adaptive educational games hold promise in transforming language learning by making it more engaging, effective, and enjoyable. By addressing the unique challenges associated with teaching and learning less commonly taught languages, Cipher paves the way for future research and development in the field of digital game-based language learning, and in this case has inspired the development of new NLP text analysis tools for Irish.

This section exemplified the potential of combining gaming technology and CALL research with linguistic analysis to enrich language education, offering valuable insights for educators, developers, and researchers who aim to enhance language learning outcomes through innovative digital solutions.

5.4 Text Classification for Enhancing DGBLL for Irish

References: This section is based on my contribution to (Mc Cahill et al., 2024).

In this section, approaches to the development of text classifiers for Irish are explored to automate the text levelling process further. In the approach to text analysis and grading, linguistic analysis is applied to assess text complexity, as discussed in Section 5.3. Features from this approach are then used in machine learning-based text classification, which explores the application of a number of machine learning algorithms to the problem. Although the development of these text classifiers is in its early stage, they show promise, particularly in a low-resource scenario.

As explained in Section 5.3, an adaptive approach is used whereby texts may need to be of a higher or lower difficulty level depending on player characteristics and their performance in the game. It is important to ensure that the texts presented to the player are at an appropriate level, while minimising the manual analysis process, especially when dealing with large volumes of text. This section explores the development of text classification tools for Irish which are necessary to enhance the educational outcomes of Cipher.

5.4.1 Text Difficulty Classification

Text analysis and text grading has been a popular research area in linguistics as it can aid language learners to progress gradually by building their vocabulary and other language skills. Much of the research to date surrounding automatic text analysis and text grading has been carried out on major languages such as English (Balyan et al., 2018; Ding et al., 2022; Pujianto et al., 2019) while languages such as Irish have not been researched to the same extent. Our goal is to apply the tools used for text grading and analysis in other languages to the Irish language. As discussed in Section 5.3.2, previous research (Ó Meachair, 2019; Uí Dhonnchadha et al., 2022, 2024) shows that lexical and grammatical complexity play an important role in text grading for Irish. Therefore, lexical, grammatical and frequency measures were calculated as input features to the machine learning (ML) models.

5.4.2 Datasets

5.4.2.1 Test Set

In order to build a text difficulty classifier for Irish, a suitable dataset must be built, since none currently exist for the Irish language. To create our dataset, we need to collect as much labelled Irish text data as is publicly available across the internet. We decided to focus mainly on two websites: `ccea.org.uk` which is an Irish language resource for schools in the UK and `scoilnet.ie` which is a primary and post-primary school website that contains Irish resources for different class groups. Texts from each of these websites were extracted along with their respective labels that can be used to predict the class (grade) range for a sample of Irish text at the primary and secondary school level. We decided on five levels, with 1 representing the first-2nd class (ages 6-8), 2 representing the third-4th class (ages 8-10), 3 representing the fifth-6th class (ages 10-12), 4 representing the lower secondary / middle school level (ages 12-15) and 5 representing the upper secondary / high school level (ages 15-18). This test set consists of 190 labelled non-translated Irish text samples from the two websites: `ccea.org.uk` and `scoilnet.ie`. It also contains some manually labelled Irish stories used in the Cipher game.

5.4.2.2 Training Set

Since there was not enough labelled Irish data across these websites to train an effective ML model, we explored other options to get more training data, in particular machine translation of existing labelled text datasets for the English language. One of such publicly available datasets is Clear Corpus (Crossley et al., 2023) [22], which contains thousands of English text excerpts, with various difficulty metrics calculated for each. There are texts in different genres such as fiction, history, science and

[22] `https://github.com/scrosseye/CLEAR-Corpus`

poetry, with a combination of different difficulty scores such as the Automated Readability Index and Flesch-Kincaid Grade Level (Kincaid, 1975), as well as the Crowdsourced Algorithm of Reading Comprehension (Crossley et al., 2019) and the Coh-Metrix L2 Readability Index (Crossley et al., 2008).

The Flesch-Kincaid Grade Level was previously discussed, along with Flesch Reading Ease and the Dale-Chall Formula, in Section 5.3.1. Below are definitions of some additional readability metrics:

- Automated Readability Index: This formula estimates the grade level required to comprehend a text based on character counts per word and words per sentence (Kincaid, 1975).

- Crowdsourced Algorithm of Reading Comprehension (CAREC): Proposed by Crossley et al. (2019), CAREC employs crowdsourced human judgments of text difficulty and integrates linguistic features such as syntactic complexity to predict text readability.

- Coh-Metrix L2 Readability Index: This index uses cognitive and linguistic metrics to assess readability, particularly for second-language learners (Crossley et al., 2008).

The Clear Corpus also contains a unique difficulty metric called BT_easiness (Bradley and Terry, 1952) which was calculated using manual rankings by teachers, who were given two texts and asked to rank which was more difficult.

The first step in making this dataset useful for our project was to translate each of the 3195 excerpts into Irish, using the Google Translate library in Python. This tool was chosen because the translations were reasonably acceptable (Dowling, 2022) and we assumed that a more difficult English text translated to Irish would be more complicated than a simpler English text translated to Irish, i.e., the difficulty labels would be preserved. Additionally, Google Translate was free, easy to integrate, and supported English-Irish translation, making it suitable given the constrained timeline for this task and the limited availability of alternative systems and resources.

Once the text was translated, we needed to use the different difficulty labels to create an overall level that corresponds to the levels 1-5 mentioned above for Irish L2 school learners, which probably will not coincide with the L1 English grading. We first looked at the given lexile level assigned to the respective English texts to see how many texts there were at each different grade level. Lexile framework measures text difficulty and reader ability to match readers with texts they can comprehend at around 75%, based on semantic difficulty and syntactic complexity (Lennon and Burdick, 2004). We realised most of the texts were at higher grade levels 9th grade + (level 5) and there were not many texts at the lower grades (level 1). We then mapped the BT_easiness, L2 Readability Index and lexile level scores to an appropriate level 1-5. An average of these three levels was calculated to get an overall level which was rounded to the nearest whole number. To validate how accurate the levels were for Irish we calculated some automatic difficulty measures used in the Clear Corpus on the Irish translated text. We calculated Flesch-Kincaid and Automated Readability Index on the Irish text and converted these grade scores to our levels 1-5. We then compared this to our BT_easiness, lexile level and L2 Readability Index average level, and found a good overlap. We then incorporated these scores into the calculation of the final level label. One was added to each label as these scores assumed Irish as a first language whereas for most students across the country that is not the case. When consulting Irish primary school teachers they recommended this increase and said that the easiest text in the dataset would probably be too challenging for most 1st and 2nd class students, which resulted in data labelled 2- 6 to be used for training.

To get Irish data for 1st-2nd class students for use in training our model we had to find another text source. After finding some basic 1st- 2nd class level sentences on the web we used these to prompt ChatGPT [23] to generate more text excerpts. This tool was selected its ability to generate text in Irish and its partial understanding of the contextual relationships between Irish words (Ní Chiaráin et al., 2023). Furthermore,

[23]https://chatgpt.com

its ease of integration and the limited support and resources available for alternative options for Irish were crucial factors in the decision. We looked over each of these generations, making changes and deletions where necessary. Ultimately we were able to add 180 level 1 (1st-2nd class) excerpts to our training set. The training set was then split to create a validation set for the models. This resulted in 2610 entries in the training set, and 653 rows in the validation set – see Table 5.9.

Dataset Split	**Total Samples**	**Source**
Train	2610	Clear Corpus (translated), chatgpt
Validation	653	Clear Corpus (translated), chatgpt
Test	190	ccea.org.uk, scoilnet.ie, cipher

Table 5.9: Dataset statistics.

5.4.3 Methodology

5.4.3.1 Baseline Features

As detailed in Section 5.3, this method involves calculating linguistic measures specifically for Irish on pre-graded data and using these measures as features to predict the difficulty levels. To investigate the most useful linguistic measures for Irish texts, pre-graded texts for use in Irish primary schools were used. Stories from Séideán Sí (SS) and Taisce Tuisceana (TT) were sourced on `www.cogg.ie`. Various lexical and grammatical measures were calculated for this data set. For this data, the lexical measures TTR (type token ratio), WTR (word type ratio) and CTTR (corrected type token ratio) as well as grammatical measure WDSEN (average number of words per sentence) appeared to be best at distinguishing between each age group showing an increase between 1st to 6th class stories, as shown in Figure 5.18. These four metrics were then calculated on our training and test data and used as the baseline features to train our model.

When performing a machine learning task through traditional methods, there are many steps involved. These include data preparation, feature engineering, model training and evaluation. With traditional methods, each of these steps needs to be performed manually, and expertise is needed with data cleaning, feature engineering, and hyperparameter tuning. These manual tasks can prove to be cumbersome for data experts and difficult to achieve for non-data experts. AutoML is an automated machine learning process that only requires manual work with data ingestion, the first step of the pipeline. The system automatically handles data preparation, end-to-end model building, and evaluation. This helps non-experts to carry out machine learning tasks, and saves data scientists time with data cleaning and exploring different models and features (Karmaker et al., 2021).

A basic AutoML experiment was run on the training and validation data using Pycaret [24] and it was found Logistic Regression performed the best.

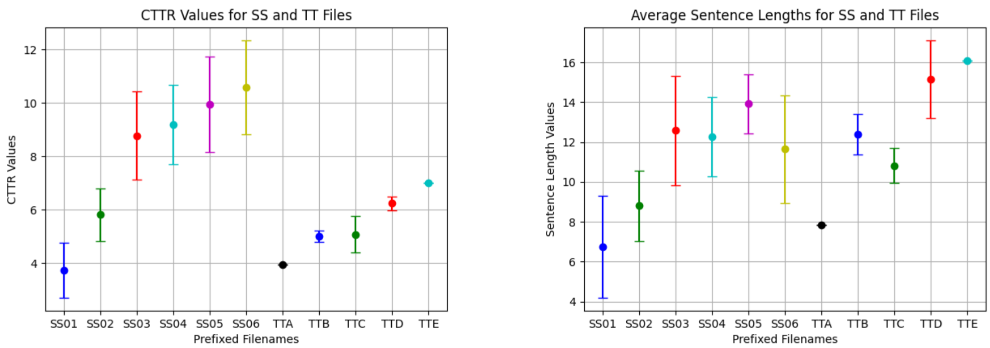


Figure 5.18: Recap - Left, CTTR values for Séideán Sí (SS) and Taisce Tuisceana (TT) texts. Right, Avg. sentence length values for Séideán Sí (SS) and Taisce Tuisceana (TT) texts

5.4.3.2 Classification with Traditional ML

Features used in the traditional ML experiments are Tf-Idf-weighted word counts (Ramos, 2003). Tf-Idf features take into account the frequency of a word in a document in proportion to the amount of documents overall that the word occurs in. To prepare the texts for Tf-Idf vectorisation, stop words were removed (using a custom made list for Irish) and words were lowercased.

Algorithms before deciding which multi-class classification algorithms to use, a

[24] `https://pycaret.org`

basic AutoML experiment was run on training and validation data using Pycaret. In order to determine whether the accuracy of the classification algorithms would be higher when trained on a set of balanced classes, we experimented with oversampling using Synthetic Minority Oversampling Technique (SMOTE) (Chawla et al., 2002). SMOTE is used for classification tasks in order to synthesise or create new values that are similar to those belonging in the minority class. The values must be numerical in order for the SMOTE technique to work. This technique generates similar points based on the 'k-nearest neighbours' similarity formula and the values can be treated as that of a feature space.

The selection of these models was informed by the results of the AutoML evaluation, which ranked classification algorithms based on their accuracy. The four models with the highest performance were subsequently chosen for manual experimentation. The four models were trained on two versions of the training data: the original version and the SMOTE oversampled version. The four classification models used for the experiment were the ridge regression, logistic regression, extreme gradient boost (XGBoost) and random forest classifiers. A brief overview of these models is as follows:

- Ridge regression, a linear model that introduces L2 regularisation (also known as ridge regression or Tikhonov regularisation) to mitigate overfitting by penalising large coefficients (Bovik, 2010; Hoerl and Kennard, 1970).
- Logistic regression, a probabilistic model often used for binary and multiclass classification, leverages the logistic function to predict probabilities and classify instances based on decision thresholds (Hosmer Jr et al., 2013).
- Extreme gradient boosting (XGBoost), a high-performance implementation of gradient boosting, optimises prediction accuracy through iterative decision tree construction and efficient regularisation techniques (Chen and Guestrin, 2016).
- The random forest classifier, an ensemble learning method that constructs multiple decision trees and aggregates their predictions to improve accuracy

and reduce overfitting Breiman (2001).

5.4.3.3 Neural Network Classification

Features The default Tokenizer class in tensor flow was used to vectorise the text. The input text was divided into individual words or tokens, with unique words mapped to integer indices.

Algorithms We experimented with deep learning models in the form of neural networks in an attempt to capture more contextual information and non-linear relationships in our data. Recurrent Neural Networks (RNN) including uni- and bi-directional Long Short-Term Memory (LSTM) networks were tried, as well as Convolutional Neural Networks (CNN) (Hochreiter, 1997; Kim, 2014).

- RNNs are designed to handle sequential data by maintaining a memory of previous inputs through recurrent connections, enabling modelling of dependencies across time steps (Mienye et al., 2024).
- LSTM networks, a type of RNN designed to mitigate the vanishing gradient problem through mechanisms such as memory cells and gating functions. LSTMs can learn long-term dependencies and are effective for sequential data modeling (Hochreiter, 1997).
- Bidirectional LSTM networks process data in both forward and reverse temporal directions, allowing the model to leverage the context of the past and future (Schuster and Paliwal, 1997).
- Originally developed for image processing, CNNs have been successfully adapted for text classification tasks. By applying convolutional filters, CNNs effectively capture local semantic patterns in text Kim (2014); LeCun et al. (1998).

The choice to use neural network-based models, such as LSTMs and CNNs, was informed by their demonstrated ability to capture contextual relationships in textual data (Hochreiter, 1997; Kim, 2014). The selection of these architectures was further guided by input from the NLP expert on our team, who recommended them as effective methods for benchmarking alongside traditional machine learning techniques and pre-trained language models. We experimented with the number of layers, embedding dimension size and learning rate to find the parameters that worked best for our data.

5.4.3.4 Pretrained Language Models

In addition to traditional ML classification and Neural Networks, experiments were run to investigate the performance of pre-trained neural language models on the text difficulty classification task. We fine-tuned language models that have been pretrained on multilingual data and/or Irish data. Two language models were used – multilingual BERT (Devlin et al., 2019) and monolingual gaBERT (Barry et al., 2021). Multilingual BERT was pre- trained on Wikipedia text with 104 different languages, and the gaBERT model was pre-trained solely on Irish text, including Irish language Wikipedia text, the Irish side of English Irish parallel corpora and the National Corpus of Ireland (Kilgarriff et al., 2006).

During tokenisation for gaBERT, the maximum padding length was set to 512 to match the predefined sequence length of multilingual BERT. This value, the default for multilingual BERT, ensured consistency in sequence lengths during model training. Initial attempts to tokenise the text for gaBERT without setting this padding length resulted in errors, as Python flagged uneven tokenisation of text excerpts. By setting the padding length to 512, tokenisation succeeded.

The performances of the models were measured based on training/validation loss and validation accuracy. Both models were trained for 3 epochs.

5.4.4 Text Classification Results

Table 5.10 summarises the different classification algorithms and language models used, along with their accuracy scores against the validation set and unseen test set.3

For all models, we observe that there is a substantial difference in accuracy

Model	**Val**	**Test**
LR Baseline Features	62	41
LR TFIDF w SMOTE	56	43
LR TFIDF w/o SMOTE	52	42
RR TFIDF w SMOTE	56	41
RR TFIDF w/o SMOTE	55	41
mBERT	77	40
gaBERT	**80**	31
bi-LSTM	54	**50**
CNN	51	47

Table 5.10: Classification accuracy on the validation and test sets. LR: Logistic Regression. RR: Ridge Regression.

between the validation and test sets. This trend can be explained by the fact that the validation set texts have been translated from English or, in the case of the simpler text, generated by a large language model, whereas the test set texts are Irish-language text used to teach Irish. The best performing approach on the test data was the bi-LSTM neural network (50%), followed by CNN (47%). The best models to choose when the training/test data align are the fine-tuned language models (gaBERT and multilingual BERT) since these are the top performing models, by a large margin, on the validation data. However, this performance did not translate to the unseen data, highlighting the substantial differences between the training/validation data and the test data. We believe that the poor performance on the unseen data was due to the language models overfitting to the training data, which limited their ability to accurately classify text outside of its sampling. This could also have been influenced by the sparsity of text data available and the lack of diverse vocabulary in the data used for the project.

The test data comes from two sources: ccea.org.uk and scoilnet.ie. The Logistic Regression model with baseline features performed better on documents from CCEA, whereas this was not the case for the bi-LSTM classification. Feature importance for the Logistic Regression model with baseline features was found by retrieving the absolute coefficient value for each feature. As illustrated in 5.19, the type-token ratio had the highest absolute coefficient value, suggesting that it may have been one of

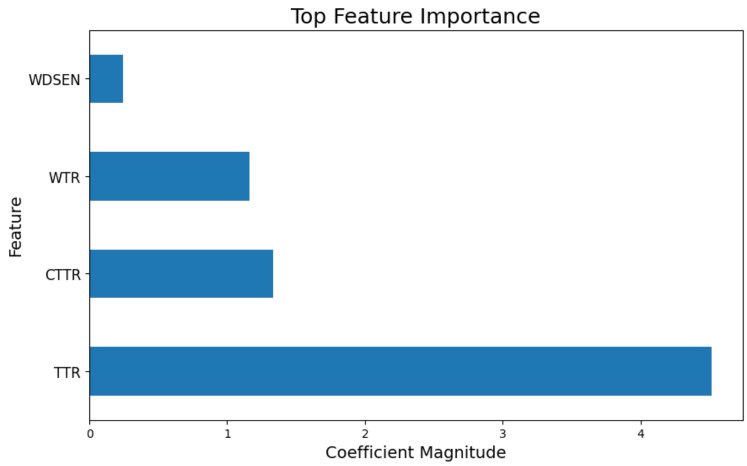


Figure 5.19: Baseline features - relative importance.

the more influential baseline features in determining text difficulty for this task. The difficulty classification appear to have been more influenced by the lexical diversity of the sentences. However, further research is needed to confirm this finding.

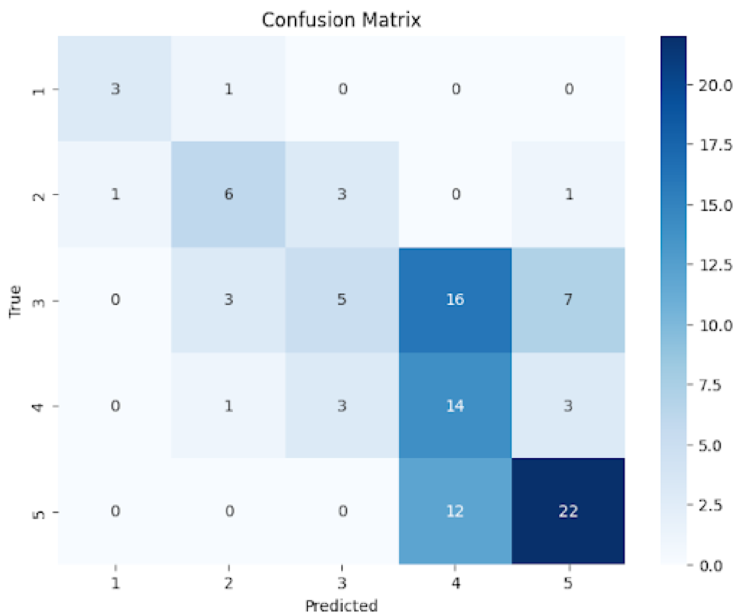


Figure 5.20: bi-LSTM confusion matrix for unseen Data (scoilnet only).

Figure 5.20 depicts the confusion matrix of the bi-LSTM network on the Scoilnet subsection of the unseen data. The model performed the best in classifying texts of difficulty level 5. The network confused texts of level 3 with those of level 4, as well as level 5 text exhibiting similar traits to level 4 text.

5.4.5 Text Classification Summary

There is a need for NLP tools such as text classifiers for low-resource languages, which can help DGBLL developers select suitable texts for language learners. In this section, we have outlined a series of machine learning experiments on the task of text difficulty classification for Irish. Predictive features were developed based on text analysis of pre-graded Irish resources, and a variety of classification algorithms were tried, including classical and neural approaches as well as neural language model fine-tuning.

The current results show potential, though the models did not perform as well as expected. We speculate that the reasons for this include:

- Sparsity of Irish text data. In particular, there is a lack of classified Irish text data available for training.
- There were very few similarities (vocab, grammar, etc) between the text data in the unseen dataset and the text data in the training/validation set. This could have made it more difficult for the models to make their classifications.
- Some of the English sentences translated to Irish could have had their contexts changed.
- More fine tuning experiments could have been run with the language models and neural networks, but were limited by the time and resources available within the scope of this task.

Further tests can be carried out on more unseen data in the future. We aim to increase the amount of Irish texts that can be used in model training and to improve data quality by seeking the help of primary school teachers to manually assign a difficulty level to the texts. Future work also involves improving the classification models so that they may be at an adequate enough standard to be implemented in the Cipher game. The aim would be to use the models to help the game ensure Irish texts are of a suitable difficulty level to assign to different age groups.

5.5 Text-to-Image Generation for Context-Specific Visual Aids

References: This section is mainly based on (Xu et al., 2023a).

5.5.1 Introduction

This section explores the application of AI image generation in CALL for Less Commonly Taught Languages (LCTLs). It delves into the potential of Text-to-Image generation (TTIG) models in creating context-specific visual aids to enhance comprehension and engagement among learners. The integration of AI-generated images in Cipher is discussed, showcasing the benefits and challenges encountered. Learner feedback indicates positive inclinations towards the AI generated images but also highlights the need for meticulous selection to address biases and stereotypes. Overall, this approach shows promise in creating culturally relevant CALL resources and improving language learning experiences for learners of LCTLs.

Images are powerful. With creative ways to harness this power, images can be used in education to enhance student engagement. For instance, Callow (2012) presented a pedagogical strategy that leverages students' inherent affinity for images to promote greater participation and involvement in the classroom setting. Research suggests that pictures are more readily identified and retained in memory than words, and visual stimuli are processed at a substantially faster rate compared to textual information (Schroeder et al., 2011). The integration of images and text in CALL can provide numerous advantages, specifically the use of visual imagery can serve as a powerful tool for stimulating learners' interest and engagement, thereby enhancing the overall efficacy of the instructional process.

In the context of CALL for LCTLs, the incorporation of graphic design elements can be of great benefit. However, due to the relative scarcity of resources available for LCTL CALL development (Ward, 2015b) the inclusion of visual design features may be considered a luxury. For instance, in a typical educational game development scenario, the visual elements usually require graphic designers to create imagery based on specific criteria, such as the game's theme, suitability for a certain group of people (e.g., school children), and maintaining cultural relevance. This process is time-consuming and expensive, and many CALL projects focusing on endangered and indigenous languages do not have access to graphic designers due to project scale and resource limitations. Therefore, we propose AI image generation as a more efficient and cost effective approach to creating context-specific imagery in CALL. Image generation tools like Midjourney are able to generate high-quality context-specific images based on descriptive prompts.

5.5.2 Methodology: TTIG in CALL for LCTLs

Images can provide more context for the learning materials delivered through CALL. For example, context assists in reading, and images can be used to enhance context. In Cipher, AI-generated images are employed as visual aids to reinforce reading comprehension and enhance gameplay. The game presents traditional stories and fairy tales to learners, with each page containing approximately 35 words. The images for these pages were generated using an iterative process, as shown in Table 5.11.

Initial prompts for the images were fed into the Midjourney and reviewed. For example, as shown in Table 5.11, the initial prompt was 'mystical boy with thumb in his mouth touching fish roasting on a spit over large fire'. However, the results were unsatisfactory and were rejected. The prompts were then modified to achieve better results. The revised prompt, as demonstrated in Table 5.11, was more concise: 'mystical boy touching fish roasting on a spit over large fire'. Once an image was deemed suitable, further related images for other parts of the story were generated until all the required images had been generated. This process led to the creation of the image used in the third example in Table 5.11. This image was incorporated

Result	**Images**	**Prompt**
Rejected		Mystical boy with thumb in his mouth touching fish roasting on a spit over large fire
Improved		Mystical boy touching fish roasting on a spit over large fire
Selected		The prompt is the same as the second example.

Table 5.11: Generated images of a boy cooking salmon using two different prompts.

into the Irish traditional story 'The Salmon of Knowledge' within the game. The screenshot displayed in Figure 5.21 depicts the utilisation of an AI generated image within the game.

Generating images with a consistent look and feel was a challenge. However, by embedding stylised words in the prompts—such as mystical, magical, mysterious, folklore, and fairytale—the generated images achieved a cohesive thematic style that aligned with the game's overall aesthetic. An example of this is shown in Figure 5.22. The illustration (Figure 5.22) was used in the story 'Hansel and Gretel' and was generated with the prompt 'a witch with her back turned to the fire in her kitchen, with mysterious, transparent background'.

Translation:

"There was a big fire under the salmon.

A blister appeared on its skin.

Oh, said Fionn, I've burnt it.

He pressed his thumb on the blister to burst it.

The skin was hot.

He burned his thumb.

He put his thumb in his mouth. Finnéigeas ..."

Figure 5.21: AI generated image in the game along with translation.

Figure 5.22: Illustrations used in the Cipher game

Research and evidence have shown that visual and multi-modal texts are effective in captivating and engaging young people across various domains, such as gaming, social media, video creation, and digital text production (Callow, 2012; Schwienhorst, 2002). The utilisation of AI image generation can result in improvements to CALL materials, thereby saving time and resources while also reducing costs. The integration of this approach in CALL holds great promise as a powerful educational tool for learners, particularly in the case of LCTL CALL (Xu et al., 2023a).

Furthermore, AI image generation offers the capacity to enhance the game's thematic focus of reconnecting with the spirit of the language by incorporating indigenous and culturally specific elements, thereby fostering a deeper connection with the language's cultural roots. In the realm of indigenous mythology and folklore, AI image generation has the potential to produce captivating and unique images that can effectively bring stories to life, especially where such imagery may not have been previously available. This is particularly significant for mythological narratives within indigenous cultures, as these stories are often confined to a relatively small global audience. As a result, the circulation of folklore is limited, leading to a scarcity of related imagery. Even when some images are available, they may not be suitable for educational purposes or may have copyright restrictions.

5.5.3 Learner Feedback on AI Image Generation

This section reports on feedback from learners who have used the Cipher game with integrated AI-generated images in Stage 3. Furthermore, guidance and advice are provided for other CALL researchers considering the incorporation of AI-generated images into their projects.

A user experience investigation was conducted during Stage 3, when the AI image generation feature was first introduced to the game. It focused on the images incorporated in the game. The participants consisted of individuals aged between 8 and 12 years attending an English-medium primary school for boys (n=169). A majority of these participants (71%) reported engaging in gaming activities on a daily basis. Following their engagement with the game over two months (once every week, 30 minutes each time) the students were requested to complete a survey. The response categories in the survey were structured using a 5- point Likert scale ranging from 1=very negative to 5=very positive. Responses rated 4 or 5 were categorised as a positive assessment in accordance with the criteria established in (Xu et al., 2022). The available survey responses vary depending on the specific questions. For detailed information on the questions and survey results, please refer to Figure B.2.

Of the total 165 responses, 51% expressed a positive inclination towards the story images featured in the game. With respect to the question concerning the extent to which the images contributed to the comprehension of the narrative, 27%

of the respondents reported perceiving the story images as facilitative in enhancing their understanding. Additionally, 28% of the responses indicated that the images could potentially assist their comprehension. More than half of the respondents, 53%, expressed that they liked playing the game. A substantial majority of 66% of respondents found the game's approach to learning Irish to be more enjoyable than traditional classroom teaching. Approximately 38% of respondents expressed a positive sentiment toward learning Irish after playing the game and a little over one third of respondents (34%) believed they learned something while playing the game. More detailed information about the survey and its findings can be found in the study (Xu et al., 2023a).

5.5.4 Challenges and Suggestions for Future Work

TTIG AI is currently undergoing rapid development. New features which involve extending an image beyond its original borders were implemented in DALL·E in August 2022 (OpenAI, 2022) and Midjourney in June 2023 (Beyer, 2023). Some TTIG models (e.g., DALL·E and Midjourney) have only recently been made available to the public and, at the time of writing, there are almost no regulations currently in place for these tools. TTIG models are part of a larger AI ecosystem that has been released since 2022 including Generative Artificial Intelligence (GenAI) tools like ChatGPT. Governments and international bodies such as the European Parliament are drafting laws to monitor AI tools. These advancements highlight the dynamic capabilities of image generation while also highlighting certain challenges. The CALL community has continually explored the possibilities offered by new technologies in the language learning process. TTIG AI has the potential to become a powerful tool in the preparation of materials for CALL. It is important to investigate what TTIG AI can provide, particularly as the technology improves, while at all times adhering to national and international regulations.

Certain challenges were faced throughout the incorporation of AI-generated images into the game. Some images produced by TTIG models exhibited biases and stereotypes. Therefore, a meticulous selection process is imperative prior to the inclusion of these images in the game. Considerable efforts are required to generate improved images using TTIG models. Achieving specific outcomes often requires numerous attempts involving adjustments to prompts or variations in the generated images.

Figure 5.23: A witch embedded in the front wall (left) and a boy with a strange hand (right)

Additionally, it was necessary to make minor adjustments using additional editing tools (i.e., Photoshop), as some generated images may possess imperfections such as extra fingers on a human subject, see Figure 5.23 to the right. Unusual and unwanted 'blends', i.e., the blending of objects from the prompts, were a common occurrence. For example, a prompt like 'a witch standing in front of her house' could result in an image of a witch embedded in the front wall of a house, see Figure 5.23 to the left. Also, the representation of females in the generated images tended to depict stereotypical extremes, portraying women as either youthful and provocative or ancient and repulsive. All prompts using the word 'goddess' were provocative and not suitable for a children's game. It is also difficult to generate a series of pictures for a story which have a common look and style. However, ongoing developments, along with advancements in tools such as Scenario [25], enable greater control over

[25]`https://www.scenario.com/`

AI workflows. With more careful use of prompts and the avoidance of problematic prompt terms very good results are possible.

5.5.5 Text-to-Image Generation Summary

Section 5.5 explored the use of Text-to-Image Generation models to enhance the development of CALL resources for LCTLs. The positive feedback received from users of the CALL application highlights the potential of AI generated images in engaging learners and improving comprehension. However, it is crucial to address challenges present in some AI-generated images. There is a need to be aware of the ethical issues with TTIG, particularly the issues of bias and copyright. Continued research and development in this area can further advance the effectiveness and inclusivity of CALL resources, which may ultimately enhance language learning experiences for learners. In summary, although there are challenges in using TTIG models for image generation or ideas drafting, the benefits make it a worthwhile endeavour.

5.6 Integrating Text-To-Speech in CALL for Dyslexic Learners

References: This section is based on my contribution to (Ward et al., 2024a; Xu et al., 2024c).

5.6.1 Introduction

This section presents the development and adaptation of the Cipher game for dyslexic English learners using Text-to-Speech (TTS) Artificial Intelligence (AI) technology. Modifications to the original Irish Cipher game include simplified texts, adjusted game rules, and AI-generated audio for instructions, vocabulary, and sentences. These elements reduce cognitive load and enhance comprehension, aligning with the needs of dyslexic students. The TTS technology used produces clear, game-appropriate speech, facilitating a more engaging and supportive learning experience. This section provides a comprehensive overview of the design and development process of the dyslexia-focused Cipher game. It highlights the potential benefits of incorporating advanced AI technologies in educational tools for learners with reading difficulties. Future research is necessary to empirically evaluate the efficacy of this tool in real-world settings, involving dyslexic learners in the testing phase. This work contributes to the ongoing discourse on leveraging technology to promote inclusive education and support diverse learner needs in CALL environments.

This adaptation is specifically tailored for dyslexic learners. Focusing on the adaptation of the Irish CALL resource, Cipher for an English context, our research explores the transformative potential of digital game-based language learning to address the unique challenges faced by dyslexic individuals in reading and language acquisition. In the field of CALL, by attending to specific language needs, our research emphasises the imperative of infusing humanity into the interaction between humans and computers for all learners in the classroom. By leveraging the innovative application of TTS AI technology, we aim to create an inclusive and engaging language learning environment for dyslexic learners.

5.6.2 Design Features and Approach

The focus is on L1 English-speaking primary school children, specifically those in the 3rd grade who are struggling readers with dyslexia. These learners face unique challenges in language acquisition, which require tailored educational interventions that use advanced technology to support their needs. The primary objective of this research is to develop a tool to explore the potential of digital game-based language learning, particularly through the use of the Cipher game, in facilitating text, audio and image based language learning for dyslexic students. This project aims to explore the intersection of games and language acquisition, promoting a more inclusive approach in CALL.

The Cipher game retains all the features of the Irish Cipher. However, this version of the Cipher game incorporates several key design features tailored specifically for this context. The game content is designed to meet the needs of young dyslexic students who are L1 English speakers, with a focus on primary school children. There was also a need to make some modifications to the game rules. They are slightly adjusted to suit learners with dyslexia, ensuring the game remains accessible and supportive. With regards to TTS integration, the game employs TTS technology with an engaging voice to aid comprehension and pronunciation. The audio is carefully selected to match the game's magical theme, using a witchy and mysterious voice that is clear and slow, enhancing the gameplay experience.

To adapt the Irish CALL resource for the needs of dyslexic learners, a comprehensive redesign of language learning materials, including vocabulary, reading materials, and sentences, was undertaken. The text in the game was simplified to ensure accessibility, achieving a Flesch Kincaid reading score of Grade level of 1.8 (indicating a reading level of Grade 1) and a Gunning Fog score, which estimates the years of formal education a person need to be able to read a text of 3.7 (indicuating that it is suitable for very young readers). This simplification was crucial to make the text suitable for young dyslexic learners. The adjustments to the game rules included changes to the quality of text. The amount of text on each page of the story in the game was reduced to lower the cognitive load on learners. There were also changes to the magic spells. In the game, magic spells encode words in specific ways, creating patterns that learners can decode. Some examples of these magic spells include Bomb Switch (this spell jumbles the letters B, D, and P in a word), Hidden Harmony (this spell removes the 'h' from combinations like ch, th, or sh in a word and Silent Eva (this spell removes the silent 'e' in a word). These magic spells were designed based on common errors made by dyslexic learners, helping them recognise and correct these patterns in a fun and engaging way. Figure 5.24 shows the adapted version of Cipher for dyslexic learners. Note that there is less text but the game vibe has been maintained.

Another adaptation is the use of simplified instructions and audio support. All

Figure 5.24: Adapted version of Cipher for dyslexic learners

text instructions in the game were checked, simplified and paired with AI-generated audio. Vocabulary words and their explanations in the vocabulary also included AI-generated audio to reinforce learning through multiple modalities. Each sentence in the sentence writing part of the game also includes AI-generated audio, providing auditory support.

By incorporating these design elements and approaches, the Cipher game aims to provide a supportive and engaging learning environment for dyslexic students, enhancing their language skills through innovative digital game-based language learning. Table 5.12 provides a summary of the adaptations for dyslexic learners.

5.6.3 Text-to-Speech Discussion

An innovation in our project was the incorporation of AI TTS technology into the game. This technology produces high-quality speech with game-like characteristics, elevating the learning experience by offering lucid audio guidance on gameplay; this helps dyslexic learners more effectively channel cognitive resources to active text-based learning targets within the game, while reducing the textual demands of the wider gameplay context.

Feature	**Change**	**Motivation**
Target language	L1 young dyslexic students	Language must be at an appropriate level
Audio	Addition of TTS audio to the game	To enhance comprehension and aid pronunciation
Game rules	Adjusted for dyslexic students	Keep the game accessible and supportive
Quantity of text	Less text	Lower cognitive load on students
Magic spells	Adapted to cover specific difficulties for dyslexic learners (e.g. Bomb Switch, Hidden Harmony, Silent Eva)	Help students with decoding
Instructions and audio support	Simplified instructions and additional audio support are provided	Keep game accessible and provide additional support

Table 5.12: Adaptations for Dyslexic Learners

Our research highlights the adaptation of the Irish CALL resource to meet the specific needs of English dyslexic learners. The integration of TTS AI appears to be a valuable tool in creating an accessible and supportive learning environment. Practical insights gained from this project contribute to the ongoing discourse on tailoring interventions for diverse learner needs and the integration of advanced technologies to enhance CALL experiences. The Cipher game was designed to be an engaging experience for players and to be a fun experience for them. Learners who have played the Irish version of Cipher have reported that the game is fun and as the look and feel and game dynamics are the same in this version of Cipher, it is hoped that this fun element has been maintained

The Irish version of Cipher (for A1, A2 learners) was adapted from the original English version of Cipher (which was for CEFR B2 adults), and the dyslexia-focused Cipher is adapted from the Irish Cipher, as it was designed for a similar age/language level cohort. As noted above, it can be difficult to develop CALL resources from scratch and it can be more efficient to adapt existing resources to a particular context. This dyslexia-focused version of Cipher shows the possibilities that incorporating audio supports can provide. Subsequently, audio support was added into the Irish version of Cipher to enhance the game and support experience for learners of Irish. This section describes the adaptation of the Cipher game for dyslexic learners in the English language context. However, due to logistical constraints, it was not possible to test the app with dyslexic students and it would be important to test this with this student cohort to investigate if it is helpful for them.

5.6.4 TTS Summary

Section 5.6 underscores the importance of human-centric approaches in CALL and presents a concrete example of how TTS can be harnessed to promote inclusivity and engagement in language learning for dyslexic students. As we strive to bridge the gap between humans and computers in language education, our insights open avenues for future research and the development of effective teaching and training methods that prioritise humanity in CALL.

5.7 Results and Discussion

5.7.1 User Experience Study Results

By Stage 5 of the Cipher project, all AI components, including NLP, TTIG, and TTS, were fully integrated, with TTS being the most recent addition to the experiment. This stage involved experiments conducted in two primary schools: a public boys' school and a private girls' school. The boys' school has been part of the project experiments since the beginning and represents a typical Irish primary school. The girl's school has more resources and advantages socioeconomically. Figure 5.25 includes some photos taken during the experiments. All participants were 4th-grade primary school students, consisting of 23 boys and 30 girls, aged 10-12. The boys played the game in one session per week, with each session lasting 30 minutes, over a span of 5 weeks. The girls played the game in one session per week, with each session lasting 1 hour, over a period of 3 weeks. As the experiments were conducted separately in two different schools, real-world factors such as student availability,

Figure 5.25: Students play Cipher in class at a girls' school (left) and a boys' school (right).

teacher schedules, class timings, and researchers' availability had to be considered. This setup represents the highest level of control that could be achieved for this comparison experiment.

The evaluation used a 5-point Likert scale, with responses ranging from very negative (0) to very positive (5). Survey options may vary depending on the question. For instance, in response to the question, "Was the level of Irish too hard, too easy or about right?" The answer to the question is 0-5 (i.e., very difficult, difficult, about right, easy and very easy). Detailed questions and results of post-survey responses from boys' and girls' schools are presented in Figure B.5 and Figure B.6 in Appendix B. The comparative analysis results are displayed in Table 5.13.

5.7.2 Discussion

For questions related to general user experience (e.g., gaming experience, learning experience, usability), user satisfaction remains promising. In response to the question, "Was the level of Irish too hard, too easy, or about right?", most students from both schools rated it as "3", indicating that the text difficulty was perceived

Question	Condition	Size	Mean	SD	Results		
Did you like playing the game?	Boys'	23	3.70	2.58	Z	0.21	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)	Girls'	30	3.93	5.55	p	0.84	0.05
How would you describe your experience of playing the game?	Boys'	23	2.78	2.71	Z	0.18	Cohen's d
Boring (1), Challenging (2), Easy (3), Confident (4), Fun (5)	Girls'	30	2.97	4.75	p	0.86	0.05
Do you like the images in the story?	Boys'	23	3.30	2.15	Z	0.16	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)	Girls'	30	3.47	5.06	p	0.87	0.04
Do the images in the story help you understand the story?	Boys'	23	2.87	2.65	Z	0.26	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	Girls'	30	3.07	2.90	p	0.80	0.07
Do you like the character's voice in the game?	Boys'	23	3.22	1.02	Z	0.60	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)	Girls'	30	2.77	3.95	p	0.55	0.15
Does the character's voice help you play the game better?	Boys'	23	2.52	2.42	Z	0.43	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	Girls'	30	2.80	2.19	p	0.67	0.12
What do you think about learning Irish through the game?	Boys'	23	3.70	3.07	Z	0.17	Cohen's d
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)	Girls'	30	3.87	4.15	p	0.86	0.05
How would you compare learning or reading Irish through the game to normal classroom teaching?	Boys'	23	4.04	3.50	Z	0.07	Cohen's d
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)	Girls'	30	3.97	4.34	p	0.94	0.02
Do you think you learned anything while playing the game?	Boys'	23	3.52	2.58	Z	0.32	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	Girls'	30	3.80	3.74	p	0.75	0.08
Was the level of Irish too hard, too easy or about right?	Boys'	23	3.00	2.80	Z	0.05	Cohen's d
Too difficult (5), Difficult (4), About right (3), Easy (4), Too Easy (5)	Girls'	30	3.07	6.07	p	0.96	0.01
Did you find the game easy to play?	Boys'	23	3.35	1.50	Z	0.16	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	Girls'	30	3.50	4.77	p	0.87	0.04
Would you recommend this game to your friends?	Boys'	23	3.30	2.15	Z	0.04	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	Girls'	30	3.27	4.34	p	0.97	0.01
How do you think you are at Irish?	Boys'	23	2.09	3.50	Z	1.44	Cohen's d
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)	Girls'	30	3.20	1.41	p	0.15	0.44

Table 5.13: Comparative analysis of user experience study between boys and girls at 4th grade from two different schools.

as about right. This suggests that the texts were well-processed and appropriately levelled for the students, indicating that the NLP components (e.g., text processing, analysis, and classification) supported the intended learning outcomes. Several key points of the evaluation are discussed as follows:

Overall Enjoyment of the Game

Liking the game:

- Boys: Mean = 3.70, SD = 2.58
- Girls: Mean = 3.93, SD = 5.55

Describing experience:

- Boys: Mean = 2.78, SD = 2.71
- Girls: Mean = 2.97, SD = 4.75

The similarity in mean scores despite a higher variance in the girls' responses suggests that both groups generally enjoyed the game, albeit with a wider range of experiences among the girls.

Perception of Visuals

Liking the Images:

- Boys: Mean = 3.30, SD = 2.15
- Girls: Mean = 3.47, SD = 5.06

Images Helping Understand the Story:

- Boys: Mean = 2.87, SD = 2.65
- Girls: Mean = 3.07, SD = 2.90

These results indicate that while both groups found the visuals somewhat helpful, the boys had a slightly more favorable view of the images than the girls. The AI-generated images were generally well-received but showed potential for improvement.

Character Voice Evaluation

Liking the Voice:

- Boys: Mean = 3.22, SD = 1.02
- Girls: Mean = 2.77, SD = 3.95

Voice Helping Gameplay:

- Boys: Mean = 2.52, SD = 2.42
- Girls: Mean = 2.80, SD = 2.19

The character's voice was more appreciated by boys than girls. The lower scores, particularly from the girls, could be attributed to the perceived mismatch between the character's voice and the expected accent, indicating an area for further refinement.

Learning Experience

Perception of Learning Irish through the Game:

- Boys: Mean = 3.70, SD = 3.07
- Girls: Mean = 3.87, SD = 4.15

Comparison with Classroom Teaching:

- Boys: Mean = 4.04, SD = 3.50
- Girls: Mean = 3.97, SD = 4.34

Subjective learning gains:

- Boys: Mean = 3.52, SD = 2.58
- Girls: Mean = 3.32, SD = 3.67

Both groups found the game a beneficial supplement to traditional classroom teaching, with boys showing a slightly higher preference for the game-based approach.

Ease of Play and Recommendation

Ease of Play:

- Boys: Mean = 3.35, SD = 1.50
- Girls: Mean = 3.40, SD = 7.55

Willingness to Recommend the Game:

- Boys: Mean = 3.30, SD = 2.15
- Girls: Mean = 2.89, SD = 5.46

The ease of play was rated similarly by both groups, though the boys were slightly more inclined to recommend the game to peers, highlighting its overall user-friendliness and appeal.

Perceived Irish Language Proficiency

- Boys: Mean = 2.09, SD = 3.50
- Girls: Mean = 3.80, SD = 3.74

The girls rated their Irish language proficiency higher than the boys, suggesting a possible correlation between perceived language competence and enjoyment or engagement with the game.

T-tests were performed. This test is suitable for analysing whether differences between two groups are statistically significant (Hastie et al., 2009; Snedecor and Cochran, 1989). Z-scores, p-values and Cohen's d statistics were calculated to assess the significance of differences between the user experience responses of boys and girls. Z-scores standardises comparisons by showing how many standard deviations a value is from the mean. P-values indicate the strength of evidence against the null hypothesis, where smaller values (e.g., 0.01) provide stronger evidence than larger ones (e.g., 1). A p-value below the 0.05 threshold suggests that the results are statistically significant (Cohen et al., 2002). Statistical significance, assessed through Z scores and p-values, indicates whether an observed effect is likely to be replicable in future studies. However, it cannot be used to convey the magnitude or practical impact of the effect. For this purpose, practical significance, assessed through Cohen's d measures the effect size and offers a framework for evaluating the impact of interventions. A larger effect size may indicate a more impactful intervention, but what is 'good' depends on the field. In the context of Digital Game-Based Language Learning (DGBLL), effect sizes for between-group designs—where outcomes are assessed across two or more groups, with one group often acting as a control group—are classified as small (less than 0.35), medium (0.35 to 0.65) and large (greater than 0.65), adapted from a meta-analysis of DGBLL effectiveness (Dixon et al., 2022).

As shown in Table 5.13, no p-value fell below the 0.05 threshold, and no Cohen's d exceeded 0.35, indicating no statistically significant differences between the two groups. This consistency in results suggests the robustness of the game's design across different demographics. With one exception—the question, "How do you think you are at Irish?"—Cohen's d is 0.44, which is greater than 0.35. This does not contradict the previous statement that boys are more disengaged than girls in Irish learning. However, the slight differences observed could also be attributed to the varying socioeconomic statuses of the schools involved, as reflected in the pre-survey data.

The findings indicate a generally positive reception of the Cipher game, with no significant differences between genders from the two schools. The game's AI components, particularly in terms of NLP and visual aids, performed well, but the TTS feature's voice accent may need further improvement to better align with user expectations. The lack of statistically significant differences between schools suggests that the game experience is consistent across genders and educational settings. However, further research could explore how socioeconomic factors influence user experience in more detail.

Question	Condition	Size	Mean	SD	Results		
Did you like playing the game?	5th	32	3.03	3.77	Z	0.74	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)	4th	30	3.93	5.55	p	0.46	0.19
How would you describe your experience of playing the game?	5th	32	2.09	2.14	Z	0.92	Cohen's d
Boring (1), Challenging (2), Easy (3), Confident (4), Fun (5)	4th	30	2.97	4.75	p	0.36	0.24
Do you like the images in the story?	5th	32	2.41	4.12	Z	0.90	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)	4th	30	3.47	5.06	p	0.37	0.23
Do the images in the story help you understand the story?	5th	32	2.41	4.53	Z	0.69	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	4th	30	3.07	2.90	p	0.49	0.17
Do you like the character's voice in the game?	5th	32	2.53	3.32	Z	0.25	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)	4th	30	2.77	3.95	p	0.80	0.06
Does the character's voice help you play the game better?	5th	32	2.03	4.80	Z	0.82	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	4th	30	2.80	2.19	p	0.41	0.20
What do you think about learning Irish through the game?	5th	32	3.03	3.01	Z	0.90	Cohen's d
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)	4th	30	3.87	4.15	p	0.37	0.23
How would you compare learning or reading Irish through the game to normal classroom teaching?	5th	32	3.16	3.72	Z	0.79	Cohen's d
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)	4th	30	3.97	4.34	p	0.43	0.20
Do you think you learned anything while playing the game?	5th	32	2.88	1.36	Z	1.28	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	4th	30	3.80	3.74	p	0.20	0.33
Was the level of Irish too hard, too easy or about right?	5th	32	2.91	3.83	Z	0.12	Cohen's d
Too difficult (5), Difficult (4), About right (3), Easy (4), Too Easy (5)	4th	30	3.07	6.07	p	0.90	0.03
Did you find the game easy to play?	5th	32	3.31	2.80	Z	0.19	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	4th	30	3.50	4.77	p	0.85	0.05
Would you recommend this game to your friends?	5th	32	2.53	3.26	Z	0.75	Cohen's d
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)	4th	30	3.27	4.34	p	0.45	0.19
How do you think you are at Irish?	5th	32	3.22	5.08	Z	0.02	Cohen's d
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)	4th	30	3.20	1.41	p	0.98	0.00

Table 5.14: Comparative analysis of user experience study between 4th grade girls and 5th grade girls from the same school.

Additionally, since the boys' school had been a primary focus from the beginning of the project and more user experience studies were conducted with boys across different stages (see Appendix B), this experiment shifted the focus slightly toward the girls' school to explore how they would view the game. Besides the comparison between 4th-grade boys and girls from different schools discussed earlier, another analysis focused on the girl groups from the same school, including an additional group of 32 5th-grade girls, aged 11–13, from the same school as the 4th-grade girls in the previous analysis. Comparisons were conducted between the 4th- and 5th-grade students within the girl groups. The results of post-survey responses from the girls' school users (5th grade) can be found in Figure B.7. Table 5.14 presents a comparative analysis of user experience between 4th and 5th grade girls from the same school.

Z-scores, p-values, and Cohen's d statistics were calculated to evaluate the differences between the two girl groups' responses, as detailed in Table 5.14. None of the p-values fell below the 0.05 significance threshold, and no Cohen's d exceeded 0.35, indicating a lack of statistically significant differences between the groups. The highest Cohen's d value, as shown in Table 5.14, 0.33, was observed for the question: "Do you think you learned anything while playing the game?" While still below the medium effect size threshold (0.35–0.65), this result is noteworthy. This difference may be attributed to the adaptive learning feature being disabled during the experiment due to time constraints. As a result, the game did not adjust to differences in language ability between 4th- and 5th-grade students, which may have led one group to find the game less helpful for learning than the other. For the adaptive feature to be effective, players need extended interaction with the game and exposure to multiple stories, which was not feasible with only two stories and a total of three game sessions during the experiment. As a result, 5th-grade students may have perceived their learning as more limited compared to 4th-grade students. Once the adaptive learning feature is activated, allowing the game's difficulty to dynamically adjust to learners' proficiency in Irish, this gap in perceived learning could be addressed more effectively.

Last but not least, although the game is not inherently collaborative and is not yet a multiplayer game, some children chose to play in pairs during the experiment, fostering social interaction as they actively discussed the game and the Irish language while playing. Refer to Figures 5.26. It was encouraging to observe this behaviour.

Figure 5.26: Students playing Cipher in pairs.

5.8 AI Summary: Addressing Research Question 2.1

RQ 2.1: How can AI (i.e., NLP, TTIG, TTS) be utilised to strengthen Digital Game-Based Language Learning (DGBLL) resources for low-resource languages? The integration of AI technologies, specifically NLP, TTIG, and TTS, has shown substantial potential in enhancing DGBLL for low-resource languages. This section summarises the key findings and innovations from the implementation of these AI technologies in the Cipher game, particularly focusing on how they contribute to creating more engaging, effective, and supportive learning environments for languages such as Irish.

NLP

Natural Language Processing (NLP) tools have been instrumental in addressing the unique linguistic challenges posed by low-resource languages like Irish. In the context of the Cipher game, NLP was employed for various critical tasks, including spelling and grammatical error detection, POS tagging, text difficulty analysis and classification. These tools ensure that the language content presented to learners is accurate and appropriately levelled. The use of a POS tagger for Irish allowed the game to differentiate and highlight linguistic features such as noun gender, which is often overlooked in traditional Irish language learning settings. Additionally, NLP-driven text classification tools have the potential to enable dynamic adjustment of text difficulty in the game, ensuring that learners are consistently challenged within their Zone of Proximal Development (ZPD), thereby enhancing engagement and learning outcomes. However, a limitation of this approach is that, although automatic text classification and adaptivity have been implemented, dynamic adaptation has not been fully tested because the feature requires extended player engagement (and extended story content) to take effect.

TTIG

Text-to-Image Generation(TTIG) has played a transformative role in enriching the visual aspect of DGBLL resources. By generating context-specific images that align with the cultural and narrative context of the game, TTIG helps to create a more engaging learning experience. In Cipher, AI-generated images were used to illustrate traditional folklore stories, providing visual cues that aid in comprehension and retention. Despite some challenges related to image consistency and cultural accuracy, the use of TTIG has demonstrated that AI can significantly reduce the time and cost associated with creating high-quality visual content, particularly for languages and cultures with limited available resources.

TTS

The integration of Text-to-Speech (TTS) technology into Cipher has enhanced the accessibility of the game, particularly for learners with reading difficulties such as dyslexia. TTS provides clear and engaging audio output that supports learners in both comprehension and pronunciation. The use of AI-generated voices tailored to the game's magical theme not only aids in storytelling but also ensures that learners can fully participate in the game without relying on textual cues alone. This addition has been particularly beneficial in creating an inclusive learning environment in which all students can engage with the content effectively. However, selecting audio with the right characteristics to match the game's theme can be challenging, especially when considering the appropriate accent to suit the demographics of the learners.

Overall Impact on DGBLL for Low-Resource Languages

The integration of AI technologies in Cipher has highlighted the immense potential of AI to transform language learning for low-resource languages. By automating complex linguistic tasks, generating culturally relevant visual content, and providing audio support, AI has addressed many challenges associated with teaching and learning LCTLs. These innovations not only enhance the learning experience but also contribute to the mobilisation of minoritised languages by making them more accessible and engaging for young learners.

In summary, Chapter 5 explored the application of NLP, TTIG and TTS in DGBLL resources like Cipher, offering a promising approach to enhancing language learning for low-resource languages. These AI-driven tools helped create a more interactive, adaptive and inclusive learning environment, ultimately addressing **RQ2.1: How can AI (i.e., NLP, TTIG and TTS) be utilised to strengthen DGBLL resources for low-resource languages?** Chapter 6 focuses on the learning aspects of Cipher, examining how learning outcomes can be analysed and evaluated.

Chapter 6

Pedagogical Design and Evaluation: Blending Learning with Gameplay

6.1 Introduction

The initial phase of the research project is game adaptation from the original English version to the Irish version (Stage 1, see Section 3.4.2). Information about each stage is included in Figure 6.1. This was to prove the concept: if an Irish story is presented to students in the game, can they find the 'disrupted' words and ciphers? Does the game work and is it suitable for primary school students? Moving further, the learning evaluation phase (Stages 4 and 5) aimed to focus on the pedagogy and make sure the game not only can encourage young learners to interact with Irish learning materials in a fun way but also improve their language skills.

In game-based learning applications, gaming alone may not be sufficient or scalable to facilitate learning (Plass et al., 2015). It is the pedagogy that supports and enhances learning within the game. As noted in Chapter 3, we created stories and modified Irish myths to make them more appealing and suitable for gameplay and language learning. We designed language learning content in the game and aim to ensure it is pedagogically appropriate. We have been working with primary school teachers on aligning Cipher's learning content with the primary school curriculum for Irish. The thematic approach of the Irish curriculum might help with scaling

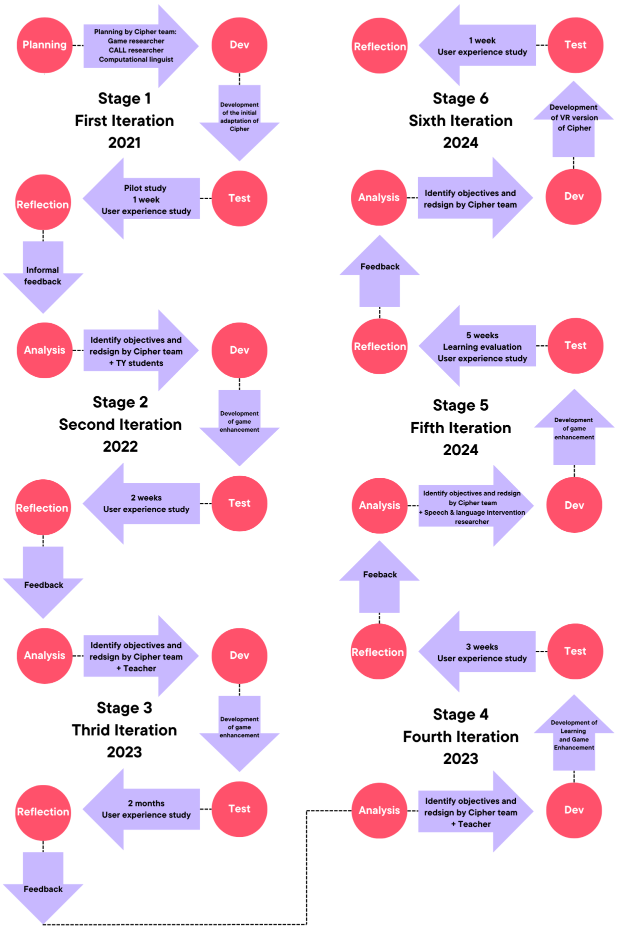


Figure 6.1: Diagram illustrating iterative cycles of Cipher.

the game/providing a framework around to build stories. Under the main theme of myths, there are subthemes of the Irish curriculum (e.g., weather, clothes, family, food and more). Challenges related to these themes are incorporated into the game for testing, and some challenges are appropriate for children at certain levels (e.g., 4th grade class, ages 9-11).

Game-based learning systems employ a variety of assessment methods to evaluate learner progress (Shute and Kim, 2014). Stealth assessment (Shute, 2011), for instance, evaluates students' performance without them knowing. This is done inside the system while students are playing the game. In contrast, overt assessment openly evaluates the students (e.g., quizzes or exams). In this research, overt assessments were implemented. An overview is provided below (with further details available in Section 6.2):

- Experimental groups: Room 1 (ID: R1) and Room 3 (ID: R3)
- Control group: Room 5 (ID: R5)
- Duration: 5 weeks (one 30-minute session per week)

The three groups of primary school students completed pretests to assess their vocabulary knowledge. After the 5 week's gaming tests, students from the three groups took a post-test to evaluate their vocabulary knowledge. By comparing the groups, the pretest and post-test results shed some light on how effective the game is for language learning. This constitutes overt assessment. During the test, students continued to receive regular instruction based on the current curriculum adopted by teachers in the traditional classroom, as Cipher is an assistive tool for language learning and motivation rather than replacing teaching. We also gathered feedback from teachers in this process. While students use the game as an aid for learning Irish, in-game data related to their language performance was collected. By analysing this data, we can conduct a stealth assessment of how the game helps students improve their language skills. This stealth assessment is planned as part of future work.

This chapter addresses **RQ 3.2: How can the effectiveness of language learning pedagogy in DGBLL be evaluated for LCTLs?** Through detailed exploration and analysis, this chapter demonstrates the integration of pedagogical strategies into game-based learning environments, ensuring that the educational content is both engaging and effective for learners. The chapter provides a comprehensive overview of the methods and frameworks assessing the overall learning experience and effectiveness.

6.2 Review of the Impact on Learning

References: This section is mainly based on (Xu et al., 2024a).

The following sections explore the educational outcomes of Cipher, focusing on vocabulary acquisition in Irish language learning. Cipher integrates engaging game mechanics with pedagogical principles, designed to enhance Irish learners' language skills. Using a double-baseline model to assess learning gains among 45 primary school students. The results show vocabulary improvements in the experimental groups compared to the control group, underscoring Cipher's educational effectiveness. Key factors contributing to its success include a pedagogical focus, cultural responsiveness, curriculum alignment, and co-creation. This study highlights the potential of Digital Game-Based Language Learning (DGBLL) applications like Cipher to effectively support language acquisition, particularly in Less Commonly Taught Languages (LCTLs).

To evaluate the educational effectiveness of Cipher, a rigorous research methodology was employed. The study utilised a double-baseline model, which involved conducting two pre-tests to establish a comprehensive baseline before implementing a 5-week intervention period and a post-test (Üstün-Yavuz, 2024). The double-baseline model is well-suited for small-scale studies where resources, time, or access to participants may be constrained. It is also advantageous for preliminary testing of interventions in smaller settings before scaling up to larger experiments. This methodology incorporates two pre-tests, allowing participants to act as their own controls over time (Üstün-Yavuz, 2024). By establishing two baselines, the design mitigates the potential effects of test familiarity, where repeated exposure to assessment tools might inadvertently influence learning outcomes, as discussed in Section 2.3.3.2. This ensures that observed improvements can be attributed to the intervention rather than repeated exposure to the test itself. Furthermore, the inclusion of a control group enhances the rigour and validity of the evaluation. This approach aligns with the project's objectives.

The research was conducted in an English-medium primary school, focusing on vocabulary acquisition as a key measure of language learning. The study employed a comparative approach involving experimental and control groups. The experimental group consisted of students who used the Cipher game as part of their learning activities, while the control group followed the class instructions without Cipher's integration. This distinction allows researchers to evaluate the effectiveness of an intervention by comparing outcomes between the two groups (Campbell and Stanley, 2015). By integrating pedagogical principles, cultural responsiveness, and curriculum alignment, Cipher aimed to provide a holistic and effective language learning tool to complement traditional practices.

6.3 Experimental Design

6.3.1 Experiment Design Difficulties

It is very difficult to carry out an ideal experiment to determine if there have been any learning gains based on the use of a DGBLL resource such as Cipher. In many experiments, the teachers involved in the experiments are also involved in teaching the students, so there is an element of control from that perspective. There may be several cohorts taught by the same teacher, which makes it easier to have a control group. Many experiments in the field of Computer-Assisted Language Learning (CALL) take place in the university context. This involved adult learners with a lecturer who has relative freedom in terms of course content. Many language learning experiments take place in a commonly taught language context (e.g., English, Spanish and French). In the context of Cipher, none of these elements were present. The Cipher game would be played in classrooms taught by primary school teachers, not by members of the Cipher team. Each teacher teaches only one class, so it is difficult to find a 'similar' control group. In the primary school context, the teacher is required to teach the set curriculum and has limited freedom to vary from that. There was no available list of vocabulary words aligned with the Cipher context for testing purposes.

6.3.2 Participants

In order to address the difficulties in terms of having a control group, the approach taken was to adhere to the standard protocol as closely as possible. Three 4th-grade classes (student ages 9–12) from the primary school participated in the experiment. One class was randomly selected as the control group (based in Room 5), while Room 1 and Room 3 were the experimental groups. The control group attended regular Irish classes, similar to the experimental groups, but without Cipher's intervention. The experimental groups received the same standard instruction with the addition of Cipher as a supplementary tool. There were 45 participants in total as some students were exempt from Irish. Each classroom was led by a different teacher. The school was an English-medium, all-boys school in a suburban setting (reflecting the standard structure of many schools in Ireland). The students had learnt Irish since their first year in primary school (age range 4 - 5) and there was a mix of abilities in each class. Some students were exempt from studying Irish due to an additional learning need. Each teacher was given an overview of the Cipher game and understood the purpose of the experiments. The researchers led the initial session of the intervention to ensure the game was properly introduced and any technical issues were addressed. For the remaining sessions, the classroom teachers were able to facilitate the game sessions themselves without difficulty. This was important, as the game was designed to be integrated into regular Irish classes without requiring ongoing researcher involvement.

6.3.3 Design of Vocabulary Survey

There are no standard vocabulary tests in Irish. Therefore, specific vocabulary tasks were developed in collaboration with teachers for the Cipher experiment. Teachers usually select words for their weekly Irish spelling test with students and this will vary by class. In order to verify the effectiveness of the use of Cipher in terms of vocabulary, it was necessary to develop vocabulary tests specifically for the Cipher experiment. It was important to have a mix of easy and difficult words, and also a mix of Cipher words and non-Cipher words. A Cipher word is a word that appears in one of the Cipher stories. On the other hand, a non-Cipher word is a word that does not appear in a Cipher story. Two tasks were designed to test students' knowledge of the chosen vocabulary words: the Vocabulary Checker task and the Vocabulary Matcher task.

Each task consists of 30 words: 20 target words, which are drawn from the vocabulary presented in the game, and 10 non-target words, which do not appear in the game. The target and non-target words are similar in terms of difficulty to ensure comparability. The inclusion of non-target words serves as a baseline to account for vocabulary development unrelated to the intervention, such as incidental learning or maturation (i.e., the natural, age-related growth of language skills). This approach improves the validity of the evaluation by providing a more comprehensive measure of change in vocabulary (Read, 2000).

Vocabulary Checker Task

The first was a Vocabulary Checker task by which students were asked to spell a word. There were 30 words in this task, with 5 easy words and 5 difficult words from the first Cipher story, 5 easy and 5 difficult words from the second Cipher story, and 5 easy and 5 difficult words not included in Cipher. Each word was spoken, read in context in a sentence, and then repeated again. The words were read out in blocks of 10 words with a short break between each block. There were two unrelated practice words before the start of the experiment as examples to familiarise them with the test procedure. The Vocabulary Checker uses the fact that spelling words from their pronunciation requires the learner to actively produce the correct written form of the word based on how it sounds. This process involves recalling the correct spelling rules and applying them, which is a productive activity (as opposed to a receptive one).

Matcher Task

The second task was a matching task, which is a receptive skill. Students are asked to match words in Irish (L2) to their meaning in English (L1). This activity typically requires learners to recognise and understand the meaning of words in both languages. It involves comprehension rather than production. The learner's task is to identify the correct meaning or translation rather than generating language output. To reduce guessing, there are more English words than Irish words in the matcher task. This task is generally easier for students than the Vocabulary Checker task, given their level of Irish, and this is also reflected in the results. The same list of vocabulary words was used for this test.

6.3.4 Devices

The school that took part in the Cipher did not have a computer room, nor did it have computing devices that were regularly used by students. The Cipher team provided a set of Android tablets (Samsung Galaxy Tab A7 Lite) to the school during the Cipher playing time. The two classes involved in the experiment used tablets to play Cipher in a 30-minute time slot (usually allocated for teaching Irish). The actual playing time was generally less than 30 minutes as time was required to distribute the tablets to the students and for them to log in. Likewise, time had to be allocated at the end of the time slot for students to log out of the game and for the tablets to be collected.

6.3.5 Procedures

A double baseline design was used in the experiment. This involved a first pretest (pretest 1), a second pretest one month later (pretest 2), a 5-week game block, followed by a post-test. This double baseline design was adopted as researchers (Üstün-Yavuz, 2024) argue that repeated exposure to the test helps children improve anyway but if improvement 1 (i.e., the difference between pretest 1 and pretest 2 scores) is

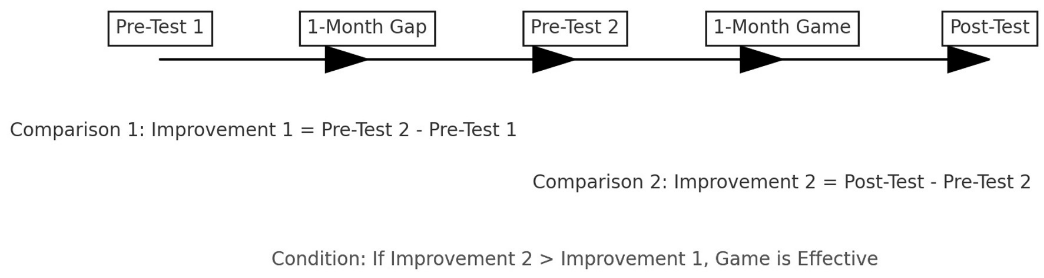


Figure 6.2: Diagram of experiment procedures

none or very small and improvement 2 (i.e., the difference between pretest 2 scores and post-test scores) is significantly greater than improvement 1, it shows repeated exposure to the test words does help them a bit but playing Cipher helps them more and it does contribute to learning. A diagram of experiment procedures is shown in Figure 6.2. Additionally, a user satisfaction survey was conducted at the end of the intervention.

6.4 Results and Discussion

6.4.1 Data Analysis

The data analysis is conducted according to a double-baseline model (Üstün-Yavuz, 2024). This allows for contrast between what students learn purely from taking the test itself, and what they learn from the game. In the case of the control group, Room 5 (see Figure 6.3), both slopes (between Rounds 1 and 2, and Rounds 2 and 3) indicate changes in learning from the tests or classroom instruction. When reading the graphs, it makes sense to compare the differences between the scores but also between the inclines (or declines) of the two slopes. To clarify, Round 1 corresponds to pretest 1, Round 2 to pretest 2, and Round 3 to the posttest.

Initial processing of the data

The data was separated into **two** overall categories for further classification: the scores achieved in the vocabulary checker exercises, which checked for the student's ability to spell the Irish words, and the vocabulary matcher exercises, which checked their ability to match the words to their English translations. In the vocabulary checker for each word, students were given one of three scores: 0, 0.5 or 1. Half scores (0.5) were given where:

- the word is correct except for accent marks (fadas)
- double consonants are given where there should only be one and vice versa
- the spelling is given in the genitive case (tuiseal ginideach) instead of the nominative case (tuiseal ainmneach) or,
- for the word 'tinneas', the spelling is given in the plural ('tinnis') instead of the singular. This only applies here as the words are near-homophones, meaning they sound almost identical but differ in spelling or meaning (Pexman et al., 2001).

In the vocabulary matcher exercise, a binary score was given, depending on whether the words were matched correctly. In both exercises, each student was given a percentage score (0-100%), representing the proportion of words they matched or spelt correctly out of the total number of words in the exercise (i.e., matcher or checker).

Within the two groups, the data was split using the student's room number and the testing round. The student's ID was recorded wherever possible, but some issues arose that made it difficult to track students throughout the three rounds. Firstly, some students did not include their ID on their test sheets. Other students' IDs did not match the IDs from the game. A final problem occurred where multiple students had the same ID in the same test round, presumably as they had shared a device for the game or may have used the same ID as a friend.

Additionally, the decision was made not to merge the two experimental groups in the analysis due to variations in teacher involvement. Specifically, in an experimental group (Room 1), the regular teacher was absent for several sessions and substitute teachers covered the class. The lack of continuity may have been an issue, as it usually takes a substitute teacher some time to become familiar with the students and their progress in each subject. This variation may have influenced the results. This variability reflects the challenges of conducting real-world educational experiments and was accounted for in the analysis. Additional factors outside the control of the study include student absences due to illness and participation in extracurricular activities. Consequently, the number of students may have varied slightly each week but not to a degree of concern, as most students were present each week.

Data categorisation

To gain an initial understanding of the performance of the three classrooms, each student's scores were split between their performance on target words, those that the student encountered in-game, and non-target words. Both lists had a mixture of easier and more difficult words.

Data distribution

Running the Shapiro-Wilk test on each of the 36 data sets (target and non-target words, in each of the three rooms, over three rounds, in both forms of tests) established whether they were normally distributed. Half of the vocabulary checker tests (9/18) had a normal distribution, as did three-quarters of the vocabulary matcher tests (15/18). Detailed data distribution can be found in Table 6.1. The Shapiro-Wilk test was selected to evaluate the normality of data distributions in this study due to its established statistical robustness compared to other alternatives such as the Kolmogorov-Smirnov test (Razali and Yap, 2011). For smaller sample sizes, particularly those with 50 or fewer cases, the Shapiro-Wilk test is considered more appropriate than the Kolmogorov-Smirnov test (Mishra et al., 2019).

Specifically regarding the data for the third round, most of the data was also normally distributed, except for the vocabulary checker non-target words in the 3rd round. Both the vocabulary checker and vocabulary matcher target word scores are

Round	Word	Distribution
1st Round Checker	Target Word	Not normally distributed
1st Round Checker	Non-Target Word	Not normally distributed
1st Round Matcher	Target Word	Not normally distributed
1st Round Matcher	Non-Target Word	Not normally distributed
2nd Round Checker	Target Word	Normally distributed
2nd Round Checker	Non-Target Word	Normally distributed
2nd Round Matcher	Target Word	Not normally distributed
2nd Round Matcher	Non-Target Word	Normally distributed
3rd Round Checker	Target Word	Normally distributed
3rd Round Checker	Non-Target Word	Not normally distributed
3rd Round Matcher	Target Word	Normally distributed
3rd Round Matcher	Non-Target Word	Normally distributed

Table 6.1: Data distributions of targeted and non-target words across rounds.

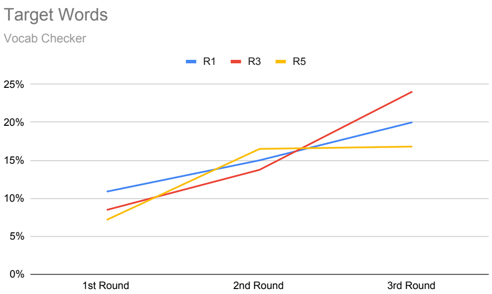
normally distributed for all students with p-values of 0.106 and 0.109 respectively. While the vocabulary matcher non-target word scores were normally distributed (p-value of 0.235), the same wasn't true in the equivalent for the vocabulary checker ($0.0003 < 0.05$). This limited the scope of statistical analysis that could be performed which is discussed in greater detail below.

Group trajectories

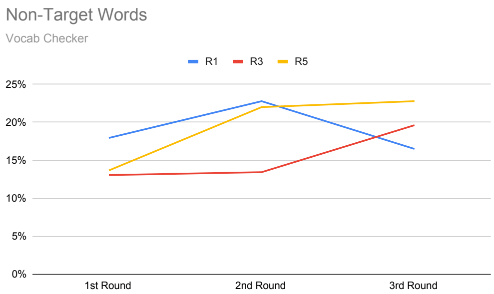
To graph the performance of each classroom, the mean and standard deviations of each of the 36 sets of scores were calculated and then plotted using Google Sheets. The data tables and graphs are shown below (see Table 6.2 and Figure 6.3).

Vocab Checker	Target words			Non-Target words			
	R1 (μ σ)	R 2 (μ σ)	R3 (μ σ)		R1 (μ σ)	R 2 (μ σ)	R3 (μ σ)
Room 1	11% 7%	15% 8%	20% 12%	**Room 1**	18% 12%	23% 15%	17% 17%
Room 3	8% 6%	14% 9%	24% 12%	**Room 3**	13% 11%	13% 11%	20% 15%
Room 5	7% 7%	17% 9%	17% 10%	**Room 5**	14% 12%	22% 14%	23% 17%
Vocab Matcher	**Target words**			**Non-Target words**			
	R1 (μ σ)	R 2 (μ σ)	R3 (μ σ)		R1 (μ σ)	R 2 (μ σ)	R3 (μ σ)
Room 1	21% 10%	24% 12%	29% 12%	**Room 1**	29% 13%	25% 10%	22% 12%
Room 3	22% 6%	26% 12%	39% 15%	**Room 3**	24% 11%	26% 6%	29% 11%
Room 5	21% 15%	30% 7%	30% 14%	**Room 5**	27% 14%	25% 12%	27% 11%

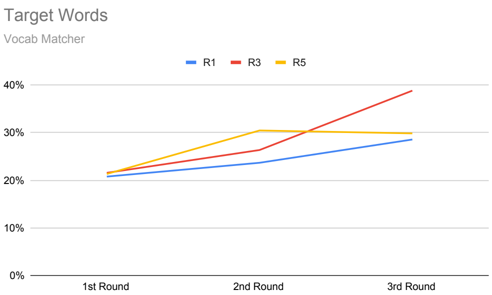
Table 6.2: The mean (μ) and standard deviation (σ) of each data set across the two exercises.



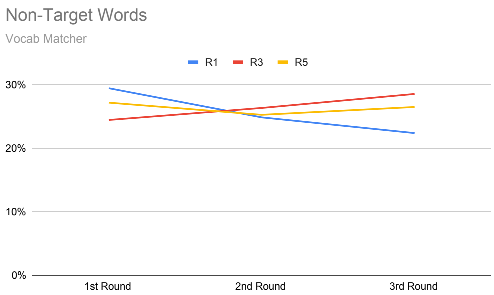
(a) Targeted Vocabulary Checker



(b) Non-Targeted Vocabulary Checker



(c) Targeted Vocabulary Matcher



(d) Non-Targeted Vocabulary Matcher

Figure 6.3: Graphs showing the trajectory of each class across the three different testing periods, for both the targeted and non-target words.
Note: 1st Round (Pretest 1); 2n Round (Pretest 2); 3rd Round (Posttest). R1 and R3 are the experimental groups, while R5 is the control group.

Interpretation

Each graph gives a different insight into the effect that Cipher has and could potentially have in an educational context. The performance of Room 1 on the vocabulary checker exhibits an almost uniform increase from pre-test 1 to the post-test. This progression from pretest 2 to the post-test is slightly greater than that between the two pretests ($m_{2-3} = 0.05 > m_{1-2} = 0.04$). This is less than had been expected and can be possibly explained by the absence of the class teacher in the intervening period as one factor among others outside the scope of this research. Room 3's performance is much closer to the expected outcome (and hoped for), as the slope between rounds 2 and 3 is greater than that between the two pretest rounds, implying the existence of an influence from the game.

Room 5, the control group, also fitted the model as very little progress was made between rounds 2 and 3. However, there is a strong increase between the two pre-test rounds. This, as well as the increases in the two charts below it (vocabulary checker non-target words and the vocabulary matcher target words), can be explained by the teacher's strong focus on Irish in the classroom, especially through the use of interactive tools such as Duolingo. As noted earlier, establishing perfect experimental control groups in real-world settings is challenging. Nevertheless, this progress appears to plateau during the intervention period. This plateau could indicate that while test familiarity from repeated exposure to the same assessments may contribute to initial gains, it has limitations when it comes to further learning from the tests themselves. The key observation lies in the changes occurring between Rounds 2 and 3—the intervention period. During this interval, the control group's performance decreases, potentially due to the absence of the intervention. This decline further supports evidence of a positive influence from the Cipher game.

Notably, the standard deviation is slightly higher in some rooms in the tests in Table 6.2, indicating that students' performance varies within the same class and potentially reflects differences in their levels of Irish proficiency.

For Figure 6.3 (b), the equivalent scores for the non-target words in the vocabulary checker also give differing results. In Room 1, there is slight progress from round 1 to 2, which is then lost in the post-test. This could be due to the aforementioned teacher's absence, as the exposure to Irish outside of the game could have been reduced. Room 3's scores on both of the pre-tests have a marginal difference but do improve after playing the game. It is not immediately clear what causes the difference, but it can be posited that the game increased their interest in learning Irish, according to the user experience studies conducted. The slope of Room 5's graph for the non-target words in the vocabulary checker is almost identical to that of both vocabulary checker and matcher in the target words, though it starts and ends at higher points. This pattern is expected for the control group, as no intervention was introduced. The observed trend involves an initial increase followed by a decrease. This consistency confirms that the control group performed as anticipated, with no unexpected factors significantly influencing the experimental process. Furthermore, the shape shows minimal difference between the target and non-target words in the control group, indicating that it serves as a valid control group.

Turning to the results from the matching exercise, we see similarly shaped slopes in the target word scores to those in the vocabulary checker. Again, the difference for Room 1 in the increase between pre-test 1 and the post-test appears almost entirely like a straight line, but there is a slightly greater incline between rounds 2 and 3. For Room 3, the increase between rounds 2 and 3 is greater than that of Room 1 for the matching exercise target words, as well as the increase in their score from round 2 to 3 for the vocabulary checker target words. Room 5 once again progressed between the two pre-tests, and then maintained the latter score in the third round.

Figure 6.3 (d) is the most ambiguous and difficult to analyse. Room 1's decline in performance can be attributed to their teacher's absence, but it is not immediately clear why the trajectory is worse here than in the vocabulary checker, even if it does start and finish at higher scores. Room 3's score again shows steady progress, which aligns perfectly with the hypothesis of learning through testing. Room 5's score in rounds 1 and 3 are the same but appear to have a slight drop in round 2. This discrepancy is quite small and could be explained by the difference in the number of people present during the different weeks, due to factors outside the control of the study, including sickness and extracurricular activities.

In summary, for the target words, the pattern was observed in both the vocabulary checker and matching exercise in both experimental groups, where the increase from pre-test 2 to the post-test was sharper than between the two pre-tests. This demonstrates that the game may have a positive effect on vocabulary acquisition, even considering that participants learned from the tests. This pattern was not observed in the control group, nor for the non-target words.

6.4.2 Application of Statistical Methods

Following on from the initial evaluations and charting of the data, different forms of statistical analyses were performed. As mentioned above, not all the data was normally distributed and so it made sense to start with non-parametric testing.

6.4.2.1 Kruskal-Wallis

The Kruskal-Wallis test is used to compare the means of three or more independent groups, in this case, the three different classrooms. While the Friedman test would appear more appropriate as a test for paired groups, allowing a comparison across the different rounds, as the aforementioned problems occurred with the student's ID it was not possible to perform.

Implementation

To conduct the Kruskal-Wallis test, the values of each dataset were ranked. It is worth noting that due to the way the students' scores were marked there were several cases where multiple students had the same score and thus were ranked with the same value.

Results

See Table 6.3.

Vocabulary Checker							
Target words				Non-Target words			
	Round 1	Round 2	Round 3		Round 1	Round 2	Round 3
H	3.85	1.25	2.22	**H**	1.62	4.97	2.10
p-value	0.146	0.535	0.330	**p-value**	0.445	0.083	0.351
Vocabulary Matcher							
Target words				Non-Target words			
	Round 1	Round 2	Round 3		Round 1	Round 2	Round 3
H	0.30	5.91	4.23	**H**	1.72	0.83	1.27
p-value	0.861	0.052	0.121	**p-value**	0.422	0.659	0.531

Table 6.3: Kruskal-Wallis H- and p-values from tests (3 classrooms, each round, 2 exercises).

Interpretation

No p-value fell below the 0.05 significance level, with the closest score coming from the second round of the vocabulary matcher, where the mean scores differences nearly reach the significance level. This can be explained by low progress made by Room 3, even less progress made by Room 1, and the relatively better performance by Room 5 at Round 2.

6.4.2.2 ANCOVA

As nothing substantial came from the non-parametric tests that could be performed, parametric tests were carried out on the data where possible. The best possible option for a test was ANCOVA, or analysis of covariance.

Implementation

To perform ANCOVA, the mean results from each class at each round were transposed to a CSV file to be read into Python for analysis. The classroom number and testing round were used as factors, and the covariate used was 'Cipher', a binary variable added to indicate whether that class was going to play the game or not. It was only possible to conduct the test on three of the four third round datasets, as the data for non-target words in the vocabulary checker was not normally distributed (see Table 6.1) and was excluded from the analysis.

Results

See Tables 6.4 and 6.5.

Vocabulary Checker				
Target Words				
	Sum Sq.	df	F	PR(>F)
Room	20.14	2	1.241	0.381
Round	205.56	2	12.671	**0.019**
Cipher	62.77	1	7.739	**0.050**
Residual	32.44	4	NaN	NaN

Table 6.4: ANCOVA findings on the 3 classrooms' scores on vocabulary checker target words.
Note: *Sum Sq* (Sum of Squares), *df* (Degrees of Freedom); df_{factor} = number of groups − 1; $df_{\text{covariate}}$ = number of covariates; df_{Residual} = total sample size − number of parameters estimated (groups + covariates); F (F-statistic); PR($> F$) (p-value) (Philippas, 2023).

Vocabulary Matcher									
Target Words					Non-Target Words				
	Sum Sq.	df	F	PR(>F)		Sum Sq.	df	F	PR(>F)
Room	299.35	2	11.563	**0.022**	**Room**	440.61	2	23.604	**0.006**
Round	195.89	1	7.451	**0.045**	**Round**	2.67	2	0.143	0.871
Cipher	149.03	1	11.513	**0.027**	**Cipher**	330.88	1	35.452	**0.004**
Residual	51.78	4	NaN	NaN	**Residual**	37.33	4	NaN	NaN

Table 6.5: The findings from ANCOVA, 3 classrooms' scores on all vocabulary matcher words.

Interpretation

The first table shows the p-values of both the Round variable and the covariate fall below the 0.05 significance level. This appears to show that playing the game did have an impact on the student's performance. The Round value shows the overall difference between rounds, and so it's logical that the improved performance of all three classes, for different reasons, led to the difference.

Regarding the scores for the vocabulary matcher, the results from the target words also appear to back up the findings from the group trajectories. Both variables and the covariate had a significant impact on the scores of the classrooms at each stage. The non-target words result once again paints a mixed picture. The low p-value of Room can be justified given the previously explained decline in Room 1, but the reason for the covariate's low p-value appears far less clear. While it can be posited that the influence of playing the game increased the student's interest for the Irish language overall, it appears very significant due to the low p-value. Perhaps more research in this area is needed.

6.4.2.3 T-tests

Two types of t-tests were conducted: independent and paired t-tests. The results from the independent t-tests did not return any significant information, while the paired t-tests did. Both are examined in the interpretation section. As with ANCOVA, t-tests were conducted only on the Round 3 (post-test) results. Vocabulary checker non-target words were not included in the analysis because they did not follow a normal distribution.

Independent t-tests

1. Implementation

The values from the independent t-tests were calculated using Python libraries (e.g., Scipy and Statsmodels). Cohen's d for each test was grouped into three ranges, low effect size (less than 0.35), high effect size (greater than 0.65), and a medium effect size.

2. Results

See Tables 6.6 and 6.7.

Vocabulary Checker	
Target Words	
	Cohen's d
Room 3 / Room 1	0.32
Room 1 / Room 5	0.29
Room 3 / Room 5	0.63

Table 6.6: Cohen's d of comparisons between classrooms for target words in the vocabulary checker.

Vocabulary Matcher			
Target Words		Non-Target Words	
	Cohen's d		Cohen's d
Room 3 / Room 1	**0.73**	Room 3 / Room 1	0.50
Room 1 / Room 5	0.09	Room 1 / Room 5	0.34
Room 3 / Room 5	0.60	Room 3 / Room 5	0.18

Table 6.7: Cohen's d of comparisons between classrooms for all words in the vocabulary matcher.

3. Interpretation

There is a medium effect size between Room 3 and Room 5 in the target words, both in the vocabulary checker and matcher, which is to be expected by comparing the experimental and control groups. The most significant difference from the data appears to be in the vocabulary matcher scores between Room 1 and Room 3, in the target words but also to some extent in the non-target words. It appears that Cipher works better when teachers are present. Furthermore, although this may not provide significant insights into the game itself, it does seem to highlight the impact of the teacher's presence on student's ability in Irish within the primary school context.

Paired t-tests

1. Implementation

Within the vocabulary checker results, it was only possible to conduct the paired t-tests on Room 3, for target and non-target words, as the rest of the data was not normally distributed for both word lists. For the vocabulary matcher, the paired t-tests compared the values that the three classes had achieved in the third round, again in the target and non-target words. Both Cohen's d and p-values were calculated, with the former categorised in the three categories and p-values being compared to a 0.05 significance level.

2. Results

See Tables 6.8 and 6.9.

Vocabulary Checker					
	Cohen's d	Mean of differences	Standard deviation of differences	t-statistic	p-value
Room 3	0.39	4.615	11.948	1.393	0.19

Table 6.8: Paired t-test between target and non-target words (Room 3 vocab. checker).

Vocabulary Matcher					
	Cohen's d	Mean of differences	Standard deviation of differences	t-statistic	p-value
Room 1	0.76	6.143	8.056	2.853	**0.01**
Room 3	0.73	10.286	14.030	2.743	**0.02**
Room 5	0.29	3.333	11.566	1.223	0.24

Table 6.9: Paired t-test between target and non-target words (all rooms, vocab. matcher).

3. Interpretation

As the other two room's datasets were not normally distributed, Room 3's results from the paired t-tests do not give a lot of information, as shown in Table 6.8. The interpretation of the vocabulary matcher results in Table 6.9 appears clearer, and again supports the argument that playing Cipher did improve the student's ability to match the Irish words to their English translations. The low p-values of 0.01 and 0.02 are quite significant, as are the Cohen's d of 0.76 and 0.73. This shows a significant difference in the student's scores in the target word list compared to the non-target words. While it's not as clear in Room 1, due to the external circumstances mentioned above, for Room 3 it does show the positive difference that playing the game had on the student's ability in Irish.

6.4.3 User Satisfaction Survey Insights

The majority of the data consisted of Likert-style responses on a scale from 1 to 5, with only a few outliers. For detailed information, please refer to the corresponding tables or bar charts. Where necessary and appropriate, these alternate responses were placed in the categories to create more robust data. For example, one of the participants said that they had found the game "Fun and frustrating" and so a half score was given to 5 and 2 for that question, respectively. The graphs for the Cipher responses are seen in Figure B.5 in Appendix B. Please note, the user experience data in this section is the same as the 4th-grade boys' data discussed in Section 5.7 as both the learning evaluation study and user experience study were conducted in the boys' school at the same stage (i.e., Stage 5 of Cipher). For detailed analysis, refer to Table 5.13.

The question in the survey, "How would you compare learning or reading Irish through the game to normal classroom teaching?" received the most positive response. Nearly three-quarters of the learners (74%) had a favourable or very favourable response to the question and preferred the game to their normal classroom Irish lessons. Just under two-thirds (65%) "like or really like" playing the game and 57% said the same regarding learning Irish from the game. From the lower scores, when asked whether the character's voice helped, 70% replied either "No" or "Not at all", while 48% said the same about the images. 57% of the learners felt that they were good at Irish.

When asked what they thought of playing the game, learners were asked to choose one word to describe their experience. Nine students said "Fun", while another nine found it challenging or frustrating. On the other hand, four found it easy. Another two found it boring.

6.4.4 Summary

Overall, the students generally perceived the game more positively than negatively. Many preferred it to traditional lessons; however, some did not find the addition of AI-generated characteristic audio to the game helpful. While many students found the game enjoyable, an equal number reported finding it challenging.

At first glance, the data does not present straightforward evidence for the hypothesis that playing Cipher did improve the student's Irish, and most of these discrepancies (e.g., vocabulary matcher scores between Room 1 and Room 3) arose from real-world factors (e.g., the absence of the regular teacher in Room 1) outside the control of this study (e.g., variation of teaching in the classroom). With that being said, there are a lot of positive indicators to be found.

It appears clear that Cipher can work really well when paired within a regular classroom context without additional assistance from researchers, as shown by the performance of Room 3 across the three rounds of testing. In the case of Room 1, where there had been disruption to regular teaching the results were more mixed.

The ANCOVA tests on the data also showed the impact that the game had on the performance in the target words, and to some extent on non-target words. The distribution of the data made restricted the testing that could be performed somewhat, however.

Finally, t-tests provided further insights into the influence of the game. Independent t-tests revealed a positive effect size between Room 3 and Room 5, the control group (Cohen's d = 0.63 for the vocabulary checker and Cohen's d = 0.6 for the vocabulary matcher). Paired t-tests on the vocabulary matcher demonstrated a large effect size between target and non-target words in the classes that used Cipher (Cohen's d = 0.76 in Room 1 and Cohen's d = 0.73 in Room 3), compared to a smaller effect size in the control group (Cohen's d = 0.29 in Room 5).

In summary, the findings indicate weak but observable evidence that Cipher positively influences language learning, particularly in vocabulary acquisition. The double-baseline model represents an advancement in the context of DGBLL, which provides a robust method for assessing the learning gains associated with the use of educational games. It highlighted that students in the experimental groups showed improvements in vocabulary checker and matcher tasks compared to the control group, demonstrating Cipher's educational potential.

6.4.5 Limitations and Suggestions for Future Research

Future research should address the limitations of this study, such as the small sample size and lack of diversity in participant demographics. The research reported here is only on a small cohort of students and it would be interesting to replicate the experiment with other cohorts of students. Conducting similar experiments in different educational settings and with larger, more diverse cohorts could provide a more comprehensive understanding of Cipher's effectiveness. The research was carried out in an all-boys school, but research into its use in an all-girls school also demonstrated that they enjoyed playing the game. However, the learning evaluation of the research was not carried out in the all-girls school for logistical reasons, but it would be interesting to do so in the future. Additionally, this study focuses on vocabulary acquisition as a starting point for assessing the effectiveness of Cipher. Further research could explore the impact of Cipher on other language skills, such as reading comprehension and writing proficiency, to fully ascertain its potential as a holistic language learning tool. Addressing these areas will help refine DGBLL applications and their implementation in educational contexts, ultimately enhancing their pedagogical value. Lastly, while the evaluation so far has focused on overt assessment (e.g., vocabulary tests), incorporating stealth assessment (e.g, log files) of learning outcomes is planned for future work. This approach will provide a more comprehensive and natural understanding of the learners' progress by unobtrusively measuring their skills and knowledge as they engage with the game.

6.5 Addressing Research Question 3.2

This chapter addressed **RQ3.2: How can the effectiveness of language learning pedagogy in DGBLL be evaluated for LCTLs?**

Chapter 3 explored the integration of language pedagogy with the engaging nature of digital games, as demonstrated through the Cipher game design process. In this research, incorporating pedagogical elements such as vocabulary acquisition, reading comprehension, and writing tasks within DGBLL has been shown to enhance learner engagement and retention (particularly vocabulary acquisition).

Chapter 6 focused on the evaluation of this integration, which was conducted using overt assessments (i.e., vocabulary matcher and checker) within experimental setups in school environments, combined with a user experience study. We analysed learners' progress in vocabulary tasks and the results highlighted improvements in vocabulary acquisition achieved through the game.

In conclusion, the language learning pedagogy was successfully incorporated into DGBLL by ensuring that the game design supports interactive, culturally contextualised learning experiences. It was evaluated through learners' progress in vocabulary tests. This DGBLL environment allowed learners to engage with LCTLs in a way that balanced educational content with gameplay, providing promising outcomes for both student engagement and learning gains.

Chapter 7

Rekindling Language Connection: Cultural Approaches Integration through Mythology and Virtual Reality

This chapter investigates the integration of ‘reconnecting to the spirit of language’ (Napier and Whiskeyjack, 2021) within the context of Digital Game-Based Language Learning (DGBLL), with a particular emphasis on indigenous languages. It begins by exploring the early attempts to incorporate indigenous language materials into Cipher, emphasising the initial stages (e.g., Stage 2) of integrating cultural elements and folklore. Figure 7.1 provides a visualisation of each iteration. These efforts laid the groundwork for creating immersive environments that not only facilitate language learning while fostering a deeper connection to the cultural heritage of the language.

As noted in Chapter 2, more and more languages around the world are disappearing at an increasing rate. This phenomenon is attributed to the declining number of speakers and the reluctance of younger generations to learn these languages, often compounded by the hesitation of older generations to pass them on. The disconnect between indigenous languages and their respective communities is a critical issue, as discussed by Napier and Whiskeyjack (2021) in the context of the

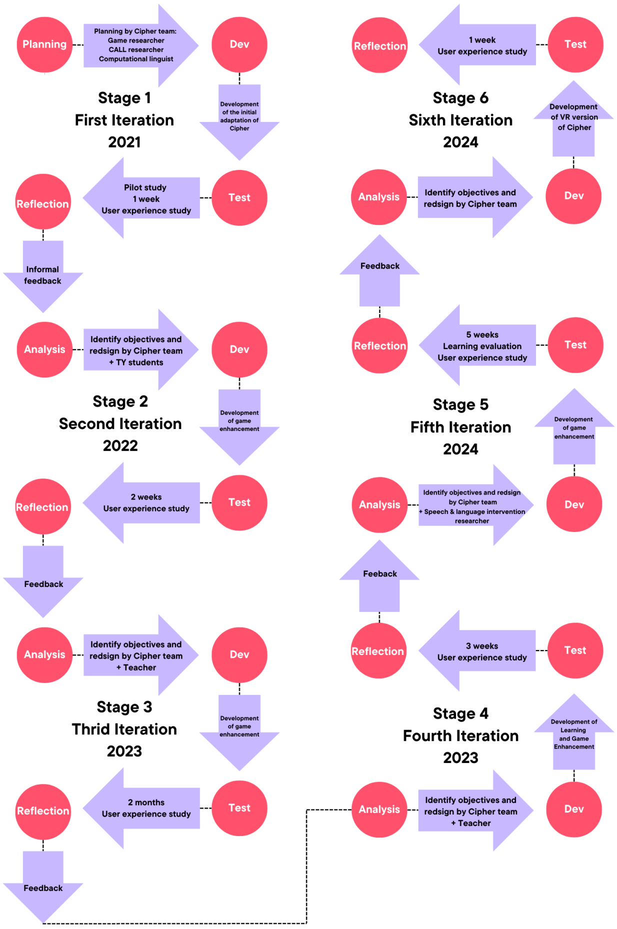


Figure 7.1: Diagram illustrating iterative cycles of Cipher.

Cree language in Canada. Their research introduces the theory of reconnecting to the spirit of the language, which involves a process of history, harms, and healing. This theory posits that the essence of a language is deeply intertwined with the land, its languages, and laws.

This chapter explores the potential applicability of Napier and Whiskeyjack (2021)'s findings to other indigenous languages, using the Irish language as a case study. By leveraging the theory of reconnecting to the spirit of the language, the project integrates Irish language lore and mythology within an immersive environment. This approach seeks to enhance the cultural connection to the language and engage learners on a deeper level, making the language learning process more meaningful and culturally relevant. This chapter sets the stage for a detailed exploration of how these theoretical concepts were operationalised in the development of a VR-based language learning game in Stage 6, which is discussed in subsequent sections.

7.1 Initial Attempts of Cultural Approaches Integration

References: This section is mainly based on (Xu et al., 2023b).

In this section, we explore the early stages of integrating the theory of reconnecting to the spirit of language into the process of repurposing indigenous language materials. Firstly, Section 7.1.1 provides a background, introducing the Dúchas resource, home to a digital archive of Irish folklore. Following this, Section 7.1.2 examines how these resources could be repurposed for DGBLL, outlining the practical steps taken to adapt these traditional resources to modern educational settings. One of the key elements in this effort was the use of Natural Language Processing (NLP) tools to process Irish texts, particularly those drawn from the Dúchas collection and other indigenous language resources. As described in Section 5.2, these tools played a crucial role in ensuring pre-processing, Part of Speech (POS) tagging, and readability adjustments for the game's text content. These efforts contribute to addressing **RQ4.1: How can existing indigenous language and culture resources be repurposed for DGBLL?** It focuses on using culturally relevant materials in DGBLL for indigenous language learning.

7.1.1 Irish Cultural Heritage and Dúchas Resource

The National Folklore Collection (NFC) is a valuable cultural resource for Ireland. Its aims are to collect, preserve and disseminate the oral tradition of Ireland (Daly, 2010; Ó Cleircín et al., 2014). The NFC contains around 2 million manuscript pages and 500,000 index cards as well as sound recording, photographs and video material. The Dúchas project [1] has been running since 2012 (Ó Cleircín et al., 2014) and its goal is to digitise historical documents. The entire Schools' Collection (e.g., 450k

[1] `https://www.duchas.ie/en/meitheal`

pages) has been scanned and indexed in the project and a great amount of texts have been transcribed (e.g., 40k pages) from the collection (Ó Raghallaigh et al., 2022). It has five main collections: the Main Manuscript Collection, The Schools Collection (TSC), The Photographic Collection, The Audio and Visual Collection and The Folk Music Archive. The focus was placed on TSC which is also known as 'Bailiúchán na Scol' (O'Cathain, 1988). This collection was gathered from over 50,000 schoolchildren from 5,000 schools in Ireland from 1937-1939. Their texts were on folklore, mythology and local traditions and in all 288,000 pages were collected. These texts provide a unique insight into Irish life and Irish language at that time.

While having this resource is valuable, particularly the hand-written archive from TSC, processing these handwritten texts with NLP tools remains challenging. Fortunately, there is a national crowdsourcing initiative that leverages support from the community to transcribe these handwritten texts into a digital format. To date, 75% of the Irish texts have been digitally transcribed. These texts were subsequently reviewed by the project team for quality assurance purposes. There is promising new research into a handwritten text recognition system for Irish which will be very useful for speeding up this process (Ó Raghallaigh et al., 2022). There is detailed metadata on each piece of text including the name, age, gender, school and location of the author as well as the teacher's name. Figure 7.2 to the left shows a scanned original handwritten text and Figure 7.2 in the middle shows the manually digitally transcribed version. This text covers part of the Irish story of Fionn Mac Cumhaill and Oisín, warrior heroes of Irish mythology. The modernised text's XML representation, which the game can use, is seen in Figure 7.2 to the right.

7.1.2 Repurposing Indigenous Language Resources

As noted in Chapter 2, research has shown that folklore and indigenous cultural elements can help learners reconnect to their language, which encourages indigenous language learning (Napier and Whiskeyjack, 2021). This section provides an overview of the process of repurposing stories from The Schools Collection of the Irish National

Figure 7.2: Scanned handwritten text - Manually transcribed digital version - XML version.

Folklore Collection for use in Cipher: Faoi Gheasa. As part of the Dúchas Project, TSC from the 1930s (c.450k pages) was scanned, indexed and transcribed, and the transcribed text and metadata were made freely available online [2]. The Irish orthographic system and the standardisation were examined since these stories were written down almost a century ago by schoolchildren.

As previously discussed in Section 5.2 the NLP pipeline facilitated the transformation of raw texts into learner-friendly content. To briefly recap, in **step 1**, TSC was searched to find suitable texts for the game. It was important to use stories that were both engaging and easy to understand, and that featured a magical or supernatural element in line with the game's theme. The metadata for each of the stories was useful in this regard. Once the original stories had been found, **step 2** involved downloading the digitally transcribed stories and their metadata from TSC. There were several files related to each story including the actual digital text and the related metadata.In **step 3**, the texts were manually reviewed, and changes were made. In **step 4**, the revised texts were checked using Gramadóir. After correcting the errors, the cleaned text was processed by the Irish POS tagger in **step 5**. The POS-tagged texts were then processed by a chunker and subsequently by the Irish Noun Phrase checker (**step 6**). Figure 7.3 illustrates the steps involved in text preparation for Cipher: Faoi Gheasa, with the NLP tools used during the process highlighted. For a detailed explanation of the processes and operations at each step, please refer to Section 5.2.

[2]`https://www.duchas.ie/`

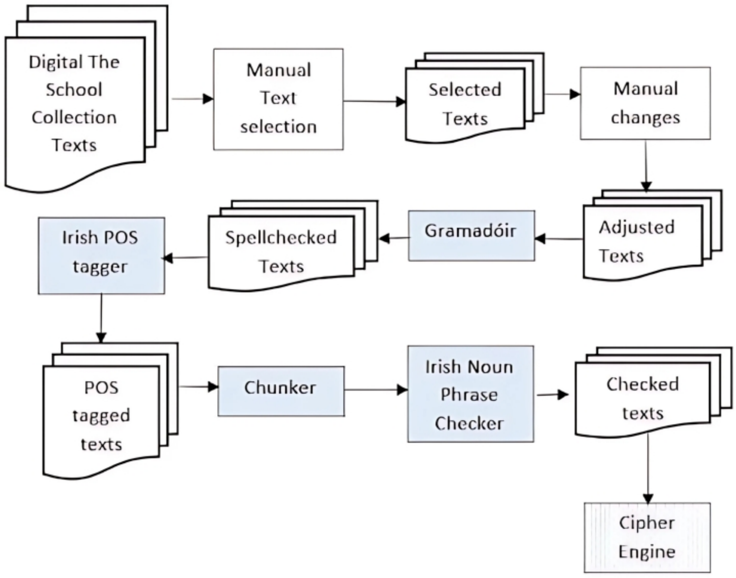


Figure 7.3: Pipeline of the text preparation for Cipher.

The next step in the pipeline is to determine the text's difficulty level—i.e., whether a text is suitable for a beginner or a more advanced learner, as well as for text progression purposes in the game. This step involved developing several text complexity measures for Irish, enabling the objective classification of texts. A more detailed explanation of the analysis and classification process is provided in Sections 5.3 and 5.4.

7.1.3 Addressing Research Question 4.1

In response to **RQ4.1: How can existing indigenous language and culture resources be repurposed for DGBLL?**—Section 7.1 summarises the process of integrating indigenous language resources into the Cipher game. This effort represents an early attempt to integrate the theory of reconnecting to the spirit of language and breathe new life into traditional Irish stories through modern technology.

The repurposing of these cultural resources into an interactive game format not only preserved the linguistic heritage embedded in the stories but also made them accessible to learners of Irish, teachers and parents, who would not usually have access to cultural heritage resources in a game can now have greater access and enjoy the benefits for educational and enjoyment purposes. This approach to integrating indigenous language and culture into DGBLL exemplifies how traditional resources can be revitalised and made relevant through technology, supporting both language learning and cultural preservation. By embedding these stories into the gameplay, learners are offered a unique opportunity to reconnect with the language and culture in an interactive environment.

7.2 Mythology Meets Virtual Reality: A VR Journey for Language Reconnection

References: This section is mainly based on (Xu et al., 2024b).

In this section, we explore the transformation of the 2D language learning game, Cipher, into a 3D VR experience to improve Irish language learning and reconnection. Despite the Irish language's official status, its use is limited in day to day life, necessitating innovative educational methods. The VR adaptation integrates the theory of reconnecting to the spirit of language through elements of Irish folklore and mythology to create an immersive learning environment. A study with 20 participants from primary and secondary schools was undertaken to evaluate user satisfaction with the VR game. The results show that the VR version enhances engagement and motivation compared to the earlier 2D evaluations. This research demonstrates the potential of VR to create transformative educational and cultural experiences in language learning. Further research could potentially investigate the impact of VR on learning.

7.2.1 Introduction

The Government of Ireland 20-year strategy for Irish (Department of Education, 2010), aims to increase daily usage of Irish, and calls for innovative approaches to language learning to increase engagement. However, the situation in primary schools presents challenges. As noted in Chapter 2, research highlights a noticeable disengagement with the Irish language among primary school students (Devitt et al., 2018; Inspectorate, 2022). Dalton and Devitt (2016) emphasises the need for innovative strategies to reverse this decline in Irish language learning. There is a clear demand for fresh, engaging tools that not only facilitate language learning but also reignite student interest in Irish. This work is driven by the pressing need to develop such tools, utilising technology and cultural relevance to create a more engaging and effective language learning experience for Irish.

In the context of indigenous languages, the theory of reconnecting to the spirit of a language underscores the deep relationship between language, culture, and identity. As noted in Chpater 2, Napier and Whiskeyjack (2021) elucidate this concept through their work with the Cree language. This approach is particularly relevant for indigenous languages, many of which face extinction as younger generations become less motivated to learn them (UNESCO, 2022a). In this study, the theory is applied to Irish, leveraging the immersive potential of VR to create an engaging and interactive learning environment. The integration of Irish folklore and mythology into the VR game aims to reconnect learners with the cultural and historical essence of the Irish language. By merging language learning with its cultural context, the aim is to cultivate a heightened sense of cultural awareness among learners.

The goal of using VR is to provide a virtual space where learners can engage with the Irish language in a deeply meaningful and transformative way, promoting not just language learning but a deeper connection to the cultural heritage of the land. By transforming the 2D version of Cipher into a VR environment, the aim is also to provide a more interactive experience for learners. This study seeks to demonstrate how VR technology can bridge the gap between theoretical approaches and practical applications, offering a novel strategy to promote the Irish language and other under-resourced languages. The VR adaptation is particularly well-suited for enhancing the cultural and historical elements of Cipher, thanks to the VR interaction loop, which includes sensory feedback (visual, audio, haptic) and a motor interface, creating a fully immersive experience for learners (Melo et al., 2020).

7.2.2 Methodology

The VR game builds on the existing 2D Cipher game and leverages the established user base and positive feedback from previous iterations, reducing the risk of user acceptance issues. Reusing resources from Cipher not only improves implementation efficiency but also ensures continuity in the user experience. This strategic approach mitigates the challenges of developing a new VR game from scratch and capitalises on the successful elements of the Cipher game. In addition, the game narrator's introduction to the game world enables players who have not seen the 2D version of the game to quickly orient themselves to the tasks and challenges that are presented.

In the development of Cipher VR, the focus is on the theory of reconnecting to the spirit of language, as a means of stimulating interest and motivation for learning the language. The immersive and interactive nature of VR provides an ideal platform to integrate language learning with cultural context, fostering a deeper connection to the language's unique background. By emphasising the cultural aspects of language learning such as historically and culturally relevant folklore, mythology and landscapes, Cipher VR aims to create a transformative learning experience that goes beyond traditional language acquisition methods. This approach addresses a gap present in the 2D Cipher game, which combines elements of gameplay, language, pedagogy, and culture in a somewhat diluted mix. In contrast, Cipher VR intentionally concentrates on the interplay between language and cultural approaches, seeking to observe the distinct and potentially powerful outcomes of this focused integration.

7.2.3 VR Game Design

This section explores the design and development of the VR adaptation of the Cipher game, marking its transition from a 2D version to an immersive VR experience. It focuses on cultural experience to enhance Irish language learning, detailing design decisions, gameplay mechanics, and technical implementation. Players engage with tasks inspired by Irish folklore, using VR hand tracking to interact with the virtual world and progress through the game.

7.2.3.1 2D Cipher Game: Initial Design and Features

As noted in Chapter 3, the Cipher Game, initially created to detect errors in English text, underwent multiple iterations before evolving into an Irish language learning game. To recap: Cipher: Faoi Gheasa is set in a magical world influenced by traditional Irish folklore and well-known fairy tales. The primary focus of the game at this stage was on reading, with players required to find enchanted words (encoded words) within various narratives integrated with engaging game elements. As noted previously, the initial design of Cipher was grounded in the concept of games-with-a-purpose and crowdsourcing. The Cipher engine was enhanced to support the creation of games in Irish, leading to the development of Cipher: Faoi Gheasa. The game's storyline involves an evil spirit casting spells on ancient legends, aiming to erase the memory of ancient spirits and the past. Players must complete specific tasks to lift these spells, rescuing the tales and spirits in the process. Game elements such as spells, power-ups, and ancient spirits transform traditional language tasks into engaging game challenges. Figure 7.4 shows a screenshot of Cipher at this stage. Up to this point, the game is entirely 2D.

Figure 7.4: Recap: A screenshot of Cipher in 2D

7.2.3.2 Transition to 3D: The Intermediary Stage

The transition from 2D to 3D for Cipher: Faoi Gheasa involved creating a three-dimensional world that maintained the core storyline and learning objectives of the game. This intermediary stage is crucial for preparing the game for its eventual conversion into a fully immersive VR experience. The 3D environment was designed to align with the game's magical theme, incorporating elements from Irish folklore and mythology to enrich the narrative and educational content. During this phase, the 3D world served multiple purposes. It was used to create animations for scene transitions, enhancing the visual appeal and continuity between different segments of the game. Additionally, new learning elements were integrated into the game, such as vocabulary learning and writing tasks, which were interwoven with the game's narrative. These elements provided a more engaging learning experience. This phase marked the intermediary stage of integrating the theory of reconnecting to the spirit of language into the game design and visualising cultural and folklore elements. Although this integration was not very prominent, it still contributed to the game's storyline and background. By incorporating Irish folklore and mythology into the 3D world, the game aims to connect learners with the cultural heritage of the Irish language. The 3D elements developed during this transition phase laid the groundwork for the VR implementation. These elements included detailed representations of folklore scenes and vocabulary-related resources, which were later reused to create a fully immersive VR environment. The resources include:

- 3D Landscape Scenery: Imaginative 3D scenes inspired by Irish folklore stories such as 'The Salmon of Knowledge', 'Cú Chulainn's hound', 'The Bull of Cooley' and 'The Land of the Young', as shown in Figure 7.5.
- Vocabulary Resources: Vocabulary lists, AI-generated images related to vocabulary, and text-to-speech (TTS) system-generated audio, aligned with common themes (e.g., food) from the Irish primary school curriculum.

This strategic approach ensured a seamless evolution from 2D to 3D and ultimately to VR, while preserving the educational and cultural objectives of the Cipher game. Like the 2D version, the 3D world-integrated version of Cipher was deployed in schools, providing an engaging learning experience even before the VR implementation. This version, along with the 2D version, allowed for practical application and testing of new features, demonstrating the game's potential to enhance language learning through interactive and culturally rich content. Figure 7.5 shows screenshots of Cipher at this stage. Up to this point, the game has been a mix of 2D and 3D, operating on portable devices such as laptops and tablets rather than in VR.

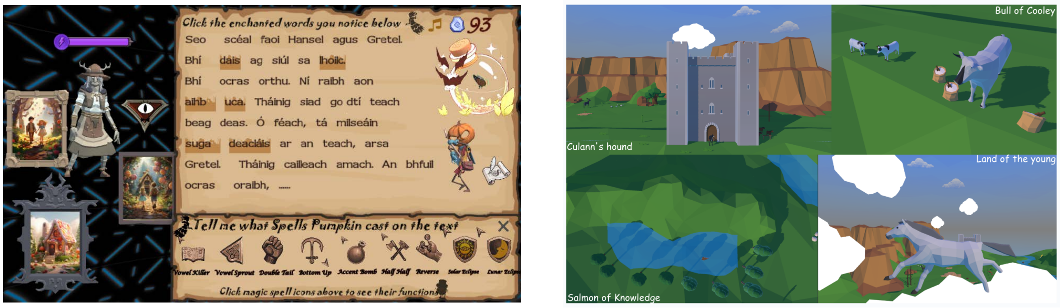


Figure 7.5: Cipher with 3D elements

7.2.3.3 Transformation to VR: Enhancing Immersive Learning Experiences

The transition to the VR version of Cipher: Faoi Gheasa represents an important step in leveraging immersive technology to enhance the theory of reconnecting to the spirit of language. The VR version, focusing solely on the Irish folklore story 'The Salmon of Knowledge', follows the same foundational game mechanics (i.e., solving language-related puzzles in order to undo magic spells) of the Cipher game but in a richly immersive environment (see Figure 7.6). The VR game retains the core mechanics of the 2D Cipher game, where players recover scrambled words (referred to as 'enchanted words') using given instructions ('magic spells'). The player's task is to spell the words correctly to advance through the game. In the VR adaptation, the focus narrows to a culturally rich story, 'The Salmon of Knowledge'. The story of 'The Salmon of Knowledge' is about Fionn MacCumhaill, who gains all the knowledge of the universe by accidentally tasting the salmon that had consumed magic hazelnuts from the Well of Wisdom. The VR environment mirrors the folklore's descriptions, creating an authentic setting for the narrative.

Figure 7.6: Players begin in a mysterious forest, awaiting the story to unfold.

The game unfolds through a series of interactive scenarios, each highlighting key moments from the mythological tale. The main objective is to unscramble words displayed in a magic book arranging letter cards on a table. Each word corresponds to a spell that must be undone to progress in the game. Players interact directly with objects in the VR world using their hands, enhancing the immersive experience and making it accessible to young learners who may not be familiar with complex controls. For example, in the first scenario, the first puzzle requires the player to restore 'liacso' to 'oscail'. They use their hands to pick up letter cards from the table and arrange the scrambled letters into the correct form of the word (Figure 7.7 to the left), thereby undoing the 'Reverse' spell, unlocking a gate (Figure 7.7 to the right), and learning that 'oscail' means 'open'. Successful completion of each word puzzle triggers corresponding events that advance the narrative and reinforce language learning through context.

The game consists of several scenarios, each blending language learning with cultural storytelling (see Figures 7.7 - 7.10).

Figure 7.7: Undo the spell on the gate: in front of a gate, players undo the 'Reverse' spell to restore 'liacso' to 'oscail' (open) to open a gate, marking the beginning of their adventure.

Figure 7.8: Undo the spell on trees: under a withered tree, players undo the 'Bottom Up' spell to restore 'nranc' to 'crann' (tree), reviving the tree beside a river and linking it to the River Boyne, thus integrating the geographical and cultural context.

Figure 7.9: Undo the spell on the well: at a dimly-lit well, players undo the 'Accent Bomb' spell to restore 'bradan' to 'bradán' (salmon), clearing the water and enabling them to catch the salmon.

Figure 7.10: Undo the spell on the fire: at a dead fire pit, players undo the 'Vowel Sprout' spell restoring 'tíné' to 'tine' (fire), reigniting the fire to roast the salmon, a pivotal event in the folklore: Salmon of Knowledge.

Throughout the game, special effects and animations enhance the immersive experience. Background music and sound effects further engage players, making the virtual environment come alive. Importantly, the game is designed to be short, around ten minutes, to minimise the risk of cybersickness, a common concern in VR applications (Cheng et al., 2017; Wu and Tu, 2023).

Hand-based interaction simplifies the learning curve, making the game accessible to a wider audience, particularly younger learners. However, due to the focus on the cultural aspect of the game, the intensity of learning has decreased considerably compared to the 2D Cipher game. By 'intensity of learning', it refers to the frequency and depth of language tasks included in the gameplay. In this initial VR version, the number of learning tasks was reduced compared to the 2D version, as the focus was on building a culturally immersive environment. In this first iteration of the VR adaptation, we prioritised the integration of cultural elements, with plans to increase the other learning components in future iterations. The transformation to a VR environment enhances the storytelling potential of the Cipher game by combining immersive technology with rich cultural narratives. This approach provides a novel and effective means of promoting Irish language learning, offering a transformative experience that extends beyond traditional educational methods.

7.2.3.4 Technical implementation

For the technical implementation of Cipher VR, Unity3D and the Unity XR Toolkit were employed to create virtual reality (VR) scenarios and interaction was facilitated by the XR Interaction Toolkit. Using Unity's free assets, the game environment was constructed, including a mountainous background scene. Adapting the 2D game for VR required extensive technical adjustments in locomotion, user interface interaction, game object interaction. For instance, it was essential to consider how users would navigate the environment, whether through teleportation, continuous locomotion, or remaining static (i.e., players do not move). To enhance exploration and immersion, users were granted a limited range of movement within the virtual environment. This design choice allows users to walk through the landscape, potentially fostering a connection to the Irish language and cultural heritage through the land (Napier and Whiskeyjack, 2021) while performing game-based and language-focused tasks in the virtual world.

3D games also require more complex controls to navigate characters in three dimensions, posing challenges for novice players (Bozgeyikli et al., 2019). To address this, room-scale locomotion was implemented (Langbehn et al., 2018), allowing users to physically move while wearing a VR headset. The VR system tracks movements, ensuring virtual movements correspond with physical ones. The XR Rig component defines the player's virtual presence, with the camera in the headset and controllers linked to virtual hands.

Graphical user interfaces, common in 2D games, are essential in VR for visualising data (Alves et al., 2020). They enable interaction through elements such as text, images, and video (Yin, 2019). In our VR game, designed for schoolchildren, we utilised Unity's world-mode canvas to display text, with UI elements triggered automatically by game actions through Unity's event system. Specifically, UI progression is managed by subscribing to game object triggers, such as detecting when a card is placed in the correct position. Upon activation of the appropriate event, the UI provides feedback to the player. To promote a structured learning experience and prevent random play, no direct interactive UI elements are included; the game advances only after the correct actions are completed. A magic book texture serves as the canvas background, enhancing both immersion and the educational experience.

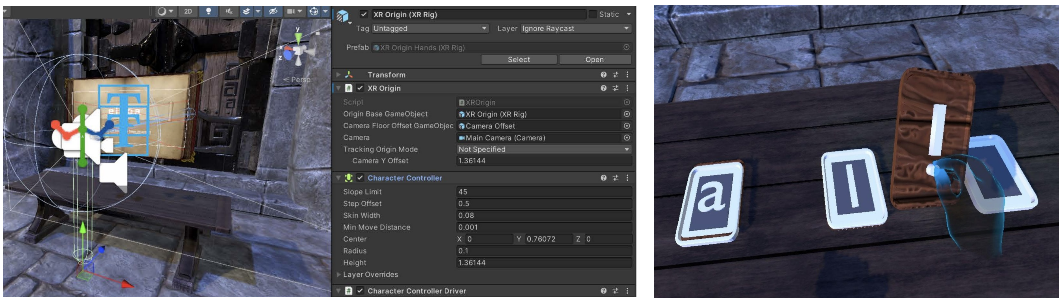


Figure 7.11: The XR Rig (left) and hand tracking (right).

Interaction with the virtual world is crucial. For school-age children, hand-tracking technology was utilised by configuring the *OpenXR* plugin for hand tracking, setting up *XR Rig* components, and adding *Direct Interactor* components to the hands (see Figure 7.11). Scripts such as *XR Grab* Interactable are used to achieve the actual grabbing effect of the player's hand with objects such as a letter card. These components collectively facilitated the implementation of hand-tracking features. In this game, players primarily use their hands to place letters into designated sockets. After a correct action is performed, Unity's event system triggers the next stage of the game. This includes particle effects to celebrate success, while objects like the table and book magically scale down and disappear, controlled by Unity's animation events. Additionally, in certain scenarios, such as when picking up a hazelnut, collision detection is employed to ensure smooth and engaging progression throughout the gameplay. The advancement of the game story is entirely automatic, requiring no additional actions from the player, which makes the experience more intuitive and accessible for young players.

7.2.4 Experimental Design

To accommodate the age group of our participants, shortened surveys were implemented, derived from a previous study on the Cipher game (Xu et al., 2022). This decision was based on our past experience where standard surveys proved too lengthy for schoolchildren. The surveys include both pre- and post-survey questions using a 5-point Likert scale to gauge various aspects of the gaming experience and its impact. Additionally, we incorporated questions specifically targeting the cultural elements of the VR game. Verbal feedback was also recorded during the gameplay to capture real-time reactions and insights. Before engaging with the VR game, participants provided baseline data through a pre-test survey. This survey included questions regarding their school and class, familiarity with VR headsets, frequency of VR gameplay, and their attitudes towards learning Irish and Irish folklore. This baseline information helped establish a starting point for assessing the impact of the VR game on participants' engagement and learning. Participants received clear and concise instructions prior to starting the VR game. This included adjusting the VR headset and understanding the mechanics of hand-based interaction within the VR environment. The instructions covered how to grab and manipulate objects in the virtual world with their hands, as well as an overview of the game's objectives and narrative. This preparatory step ensured that participants were comfortable and ready to fully engage with the VR experience.

The participants played the VR game and took approximately 10 minutes to complete. The game involved interacting with objects in the virtual world and solving puzzles by restoring words related to the Irish folklore story, 'The Salmon of Knowledge'. This hands-on, immersive activity was intended to provide a rich, engaging learning experience that connects language learning with cultural storytelling. Following the gameplay, participants completed a post-test survey to measure any changes from the pre-test. This survey evaluated aspects similar to those examined in the previous user studies, along with additional questions focused on the cultural elements and the overall impact of the VR experience. The post-test aimed to record participants' reactions to the VR game and possible shifts in participants' motivation, engagement, and connection to the Irish language and culture. We compared the results of the VR post-test with the results of the post-test for the previous 2D version of Cipher. This included reusing questions from the old pre- and post-surveys to maintain consistency in data collection. New questions were added to explore the correlation between engagement and cultural elements introduced in the VR version. Verbal feedback collected during gameplay provided additional qualitative data to complement the survey findings.

The study involved 20 participants—10 primary school students (aged 10–12) and 10 secondary school students (aged 13–17). The primary school students, all boys, had previously participated in a separate study involving the non-VR version of Cipher at Stage 5. The secondary school students were completely new to Cipher VR and comprised 4 boys and 6 girls. All participants played the VR game until completion, which took approximately 10 minutes. The primary school students had played the non-VR version in a previous study (see Section 5.7), where they engaged with the game once a week over a 5-week period, with each session lasting 30 minutes. The secondary school students played only the VR version, and this was their first exposure to the game. The primary school part of the study was conducted in educational settings, with students participating in a classroom provided for the purpose. However, as secondary schools were on break during the time of the experiment, the secondary school students were recruited through the researchers' network, and the VR test was conducted wherever was convenient.

7.2.5 Results and Discussion

7.2.5.1 Initial processing of the data

Most of the data was composed of Likert-style responses on the scale from 1 to 5, with only a few outliers. Where necessary and appropriate, these alternate responses were placed into the categories to create more robust data. For example, one of the participants said that "It was a really fun and nice irish game to play i loved it [sic]" and so this response was given a score of 5. Another student replied that they had found the game "Fun and frustrating" and so a half score was given to 5 and 2 for that question, respectively. The graph for the Cipher VR response is shown in Figure B.9 in Appendix B.

Similar questions were asked of the students that had played the 2D Cipher game with some slight variations as the non-VR version is at a more advanced stage. Therefore, comparing all the graphs to each other gives limited insights. However, the responses to the VR survey were overall more positive according to those questions that were the same in both studies. Question 8 in the Cipher survey "How would you compare learning or reading Irish through the game to normal classroom teaching?" has the most positive response. 74% of the 23 participants had a favourable or very favourable response to the question and preferred the game to their normal classroom Irish lessons. 65% like or really like playing the game and 57% said the same regarding learning Irish from the game. Respondents reported that the character's voice was not helpful (70% replied either "No" or "Not at all"), while 48% said the same about the images. 57% of the students felt that they were good at Irish. Note that the tenth question asked whether the level of Irish was right, with 3 being “about right”, with 1 and 5 meaning “too difficult” and “too easy”. By comparison, in the VR responses there are five questions which every participant either answered positively (4) or very positively (5): “Did you like the VR game”, “Do you think the VR game makes learning Irish more interesting”, “What do you think about learning Irish through the VR game”, “How would you compare learning or reading Irish through the VR game to normal classroom teaching”, and “Would you recommend this VR game to your friends”. Of these the strongest response was to the first question, where 80% of the 20 participants said that they very much liked playing the game. The less positive results were still quite strong. 80% knew well or somewhat well the Irish folklore story in the VR game. The majority of participants (70%) thought they learnt something while playing the VR game, with only 3 negative responses.

There are three other elements that are worth mentioning. First, all of the players were able to play the game without any major issues (even though 50% had never used a VR headset before nor played a VR game before) and the game was easy to play (95%). This indicates the game’s accessibility and user-friendly design. Second, the primary school students were able to play the game in their school in the real-world setting of a small classroom, which is inherently more challenging than a controlled research environment. Thirdly, feedback from educators has been positive also. One leading Irish language teaching academic stated that “this is amazing” and recognised the potential for Cipher VR in classrooms across the country. In the pre-survey, 52.4% of participants expressed an interest in Irish folklore. After engaging with the VR game, the post-survey responses indicated a significant increase in interest (the game made folklore more interesting (90%), VR brought the stories to life 90%) and 95% wanted to learn Irish through more folklore stories in VR).

7.2.5.2 Comparative analysis

The availability of statistical analysis on the data was limited by both the size and distribution of the data. Two comparisons were made: between the Cipher game and its VR equivalent, and between the primary and secondary school students that played the VR game. For the former only primary school students were included as they would have played the non-VR game previously.

In this study, t-tests were performed to determine whether there were statistically significant differences between the groups being compared. The t-test is appropriate for comparing the means of two groups, such as the responses of participants playing the VR and non-VR games, or the responses of primary versus secondary school students. This exploratory analysis focused on detecting differences between group means, regardless of direction. It aligns with the study's objectives, where no prior assumptions were made about which group would score higher or lower on survey questions, considering deviations in either direction and even non-significant differences to be of interest.

The use of z-scores complements the t-test by standardising the data, enabling comparisons on a uniform scale. As noted in Section 5.7.2, a z-score indicates how many standard deviations a particular data point deviates from the mean, providing a useful metric for comparing values across different distributions or scales. Standardisation was important in this study due to the small sample sizes and the potential variability in response scales. By transforming raw scores into z-scores, the analysis accounted for differences in means and variability, ensuring that the findings were not influenced by scale-specific differences or outliers. This approach allowed for a more accurate and meaningful comparison of participant responses (Hastie et al., 2009).

Firstly, it is important to note that the sample sizes are quite small and so there are higher margins of error to the findings. The 10 primary school participants who played the VR version of the game (see Table 7.1) are the same ten who are in the 'Primary' row in Table 7.2. Table 7.1's highest mean is the score from the number of participants who liked the VR game, as all said they liked it "Very much". The lowest value (3.30) comes from those who played the non-VR game when asked if they would recommend the game to their friends, aligning with "Maybe". The highest p-value, 0.56, appears to indicate that both non-VR and VR games were favoured over normal classroom teaching, with the VR game only being slightly more popular in that context than the non-VR game. The greatest difference also comes from the final question, where participants were more likely to recommend the VR game to a friend than the non-VR game.

In the two tables analysed, the lowest p-value observed was 0.15, which did not fall below the 0.05 significance threshold. In Table 7.2, the highest mean score ($\bar{x} = 5$) is identical to that in the other table for the question: "Did you like the game?". Conversely, the lowest mean score in Table 7.2, recorded at 3.30, was observed among secondary school students in response to the question: "Do you think you learnt anything while playing the VR game?". This score roughly corresponds to a 5-point Likert scale response of "Maybe" (3), suggesting a moderate level of agreement. Notably, this question also exhibited the greatest difference between the two groups, with a p-value of 0.3.

Primary school students were more likely to say "Yes". The lowest p-value here, and across the two tables occurs where the students were asked if they found the game easy to play, with both groups likely to respond with "Yes". While they cannot be taken to be statistically significant, the results borne out here indicate a few important points. Both games are preferred to the relatively same extent to normal classroom teaching, but the VR game was more likely to be recommended to a friend. Primary school students were more likely to feel they had learnt from the game, which was expected since the learning content was aligned with the primary school curriculum. At this stage, the goal was to test the acceptance rate of the VR transformation. Both primary and secondary students found the VR games easy to play, even though 80% claimed they were not familiar with VR devices and 50% reported they had never played VR games.

As explained in Section 5.7.2, and to maintain consistency, the effect size for between-groups designs in this study is classified as small (less than 0.35), medium (0.35 to 0.65), and large (greater than 0.65). The effect size (Cohen's d) between the

Question	Condition	Size	Mean	SD	Results		
Did you like the VR game?	VR	10	5.00	4.00	Z	0.95	Cohen's d
Did you like the game?	Non-VR	23	3.70	2.58	p	0.34	0.43
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)							
What do you think about learning Irish through the VR game?	VR	10	4.90	3.52	Z	0.94	Cohen's d
What do you think about learning Irish through the game?	Non-VR	23	3.70	3.07	p	0.35	0.38
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)							
How would you compare learning or reading Irish through the VR game to normal classroom teaching?	VR	10	4.70	2.76	Z	0.58	Cohen's d
How would you compare learning or reading Irish through the game to normal classroom teaching?	Non-VR	23	4.04	3.50	p	0.56	0.20
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)							
Do you think you learned anything while playing the VR game?	VR	10	4.10	1.90	Z	0.72	Cohen's d
Do you think you learned anything while playing the game?	Non-VR	23	3.52	2.58	p	0.47	0.24
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)							
Did you find the VR game easy to play?	VR	10	4.20	2.10	Z	1.16	Cohen's d
Did you find the game easy to play?	Non-VR	23	3.35	1.50	p	0.25	0.50
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)							
Would you recommend this VR game to your friends?	VR	10	4.70	2.76	Z	1.42	Cohen's d
Would you recommend this game to your friends?	Non-VR	23	3.30	2.15	p	0.15	0.60
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)							

Table 7.1: A comparison between the survey responses to the VR and non-VR versions of the Cipher game.

Question	Condition	Size	Mean	SD	Results		
Did you like the (VR) game?	Primary	10	5.00	4.00	Z	0.27	Cohen's d
Did you like the (VR) game?	Secondary	10	4.60	2.53	p	0.79	0.12
Not at all (1), No (2), Maybe (3), Yes (4), Very much (5)							
What do you think about learning Irish through the (VR) game?	Primary	10	4.90	3.52	Z	0.36	Cohen's d
What do you think about learning Irish through the (VR) game?	Secondary	10	4.40	2.53	p	0.72	0.16
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)							
How would you compare learning or reading Irish through the (VR) game to normal classroom teaching?	Primary	10	4.70	2.76	Z	0.25	Cohen's d
How would you compare learning or reading Irish through the (VR) game to normal classroom teaching?	Secondary	10	4.40	2.53	p	0.80	0.11
Very Bad (1), Bad (2), OK (3), Good (4), Very Good (5)							
Do you think you learned anything while playing the (VR) game?	Primary	10	4.10	1.90	Z	1.03	Cohen's d
Do you think you learned anything while playing the (VR) game?	Secondary	10	3.30	1.55	p	0.30	0.46
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)							
Did you find the (VR) game easy to play?	Primary	10	4.20	2.10	Z	0.08	Cohen's d
Did you find the (VR) game easy to play?	Secondary	10	4.10	3.52	p	0.94	0.03
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)							
Would you recommend this (VR) game to your friends?	Primary	10	4.70	2.76	Z	0.32	Cohen's d
Would you recommend this (VR) game to your friends?	Secondary	10	4.30	2.76	p	0.75	0.15
Not at all (1), No (2), Maybe (3), Yes (4), Definitely (5)							

Table 7.2: A comparison between the survey responses of primary and secondary school students to the VR version.

Cipher and Cipher VR responses, four questions had a moderate effect size ("Did you like the game?", "What do you think about learning Irish through the game?", "Did you find the game easy to play?", and "Would you recommend this game to your friends?"). See Table 7.1. This suggests that participants found the VR version more engaging compared to the non-VR version. When comparing primary and secondary school students' responses to the VR game, only one question ("Do you think you learnt anything while playing the (VR) game?") showed a moderate effect size, which is expected as the learning materials were designed for primary school students. The study at this stage focuses on user acceptance, with future work aimed at enhancing the learning aspects of the VR game. All other questions in Table 7.2 had a small effect size.

In summary, the primary objective of transitioning Cipher from a 2D to a 3D VR format was to evaluate the feasibility of adapting 2D concepts to a 3D VR environment and it also widened the reach of the game from primary school students to secondary school students and older learners. The technical complexities of developing a VR version were significant but manageable, with many 2D elements successfully enhanced in the VR context. The transitioning from 2D to VR involved major design and technical modifications. This process preserved core educational objectives while enhancing the immersive experience, providing valuable insights for similar future projects. From a storytelling perspective, the VR environment allowed for a more creative and immersive experience. Cipher VR was designed as a special, impactful experience, distinct from the daily-use 2D version. There were a lot more "wows - this is great" type comments from players of the VR version. While the players enjoyed the 2D version and wanted more, the VR version was considered something special. One post-primary school student said, "It would be a treat, not something you would play all the time, but something you would look forward to playing". Other elements worth mentioning are the ease of use of the game, the ability to play the game in a classroom setting and positive anecdotal feedback from educators.

7.2.6 Limitations and Future work

The limitations of the small sample size are recognised, which may affect the ability to detect statistically significant differences between the 2D and VR versions of the game. It is also noted that the VR transformation covers only the first task, i.e., the vocabulary task, of Cipher Faoi Gheasa. The remaining tasks will be explored in future research based on user feedback. Some progress has been made in constructing 3D scenery for other folklore stories, as previously mentioned. However, at present, only one folklore story (Salomn of Knowledge) has been fully implemented in the virtual world, with plans to integrate additional folklore narratives in the future. We recognise that a direct comparison of interaction paradigms between VR and non-VR games presents challenges. However, it is important to note that our focus was not on comparing them in detail but rather on assessing how users responded to the VR format in its early stage of development. Future studies could incorporate a more detailed assessment of participants' language proficiency to better explore the VR game's effect on learners with varying levels of expertise. An analysis according to participant gender could also be considered in future research.

While the VR version of the game demonstrated its feasibility in real-world settings with minimal instruction, technical limitations were noted, including the short game duration, which was designed to prevent cybersickness, through limited exposure to the game content. Areas for improvement remain, such as providing more extensive gameplay and mitigating any potential Hawthorne effect, i.e., the novelty factor (Adair, 1984). For example, extending gameplay sessions and exploring the benefits of longer or more frequent sessions, possibly with breaks to reduce cybersickness, could be valuable.

To draw more robust conclusions, future studies should involve larger sample sizes, extended interaction times with additional content, and more diverse educational settings to better assess the VR game's effectiveness in different contexts. There is a notable scarcity of research on the use of VR in the context of Irish language learning.

This gap in research on the use of VR in the context of Irish language learning highlights the need for further research to build a comprehensive understanding of VR's potential in this field. Future iterations could focus on expanding content, addressing these limitations and increasing its scalability and accessibility.

7.2.7 Addressing Research Question 2.2 and 4.2

Section 7.2 addressed **RQ2.2: How can VR be used to enhance DGBLL resources and create CALL environments for low-resource languages?** and **RQ4.2: How can the theory of reconnecting to the spirit of the languages be applied to indigenous language learning through DGBLL in VR?** Cipher VR further applied the theory of reconnecting to the spirit of language through immersive technology, within the context of indigenous language learning.

Unlike the 2D version of Cipher, which is designed for regular use on portable devices, the VR adaptation provides a relatively short yet uniquely immersive experience designed to make a lasting impression on the learner. This experience is achieved through the integration of Irish folklore and mythology within an immersive 3D virtual environment, where players engage directly with cultural narratives, thereby fostering a connection to the language and its cultural roots.

The transition of Cipher from 2D to VR successfully enhanced the immersive experience, integrated cultural elements, and broadened the game's audience. However, the pilot study's limitations—such as the small sample size, brief gameplay duration, and the early stage of the VR version—may have impacted the results. Despite these potential limitations, the work on the VR version of Cipher indicates that it is possible to imbue the game with cultural aspects. It also shows that reconnecting to the spirit of the language can be achieved by harnessing the enduring appeal of mythological tales and folklore, which can positively impact participants' interest in Irish folklore. The study demonstrates that relatively short, well-designed VR experiences can complement traditional learning methods, enhancing language learning through immersive, culturally rich narratives.

Chapter 8

Conclusion

8.1 Research Objectives and Questions

The overarching goal of this research was to explore innovative methods to engage students in Less Commonly Taught Languages (LCTLs), with a specific focus on the Irish language. By integrating cultural and contextual knowledge through the use of advanced technologies, this study sought to develop robust, culturally relevant resources for LCTLs. The research was driven by several key questions, each corresponding to different aspects of the study, which were investigated across the preceding chapters.

Objective 1: A Creative Approach to Engage Students in Learning LCTLs

The first objective was to find creative and effective ways to engage students in learning LCTLs, particularly within the framework of Digital Game-Based Language Learning (DGBLL). This objective was primarily addressed in Chapter 4, where the research focused on adapting existing game resources designed for dominant languages to suit the needs of low-resource languages like Irish. The corresponding research question, **RQ1: How can existing game resources designed for dominant languages be repurposed for low-resource languages within the context of CALL?**, was explored by demonstrating how game elements could be repurposed and enhanced to foster engagement and motivation among learners of LCTLs. The adaptation of the Cipher game into Cipher: Faoi Gheasa showcased how game-based learning can transform the language acquisition experience, making it more interactive and culturally relevant.

Objective 2: Leveraging advanced Technologies to Integrate Cultural and Contextual Knowledge in LCTL Learning

The second objective was to integrate cultural and contextual knowledge into the learning process of LCTLs, enhanced by the use of cutting-edge technologies. This was explored through the application of AI and VR technologies, as discussed in Chapters 5 and 7. These chapters addressed **RQ2: How can specific technologies (i.e., AI and VR) be leveraged to enhance DGBLL for LCTLs?**. Specifically, subquestion **RQ2.1: How can AI (i.e., NLP, TTIG, TTS) be utilised to strengthen DGBLL resources for low-resource languages** was addressed in Chapter 5, while subquestion **RQ2.2: How can VR be used to enhance DGBLL resources and create CALL environments for low-resource languages?** was explored in Chapter 7. The research demonstrated how these technologies could be utilised to not only support language learning but also to enrich the cultural and contextual understanding of the language. The application of AI techniques and the development of VR environments facilitated the creation of immersive, culturally enriched CALL environments, thereby enhancing the learning experience.

Objective 3: Incorporating and Evaluating Resources for LCTLs (Irish)

The third objective was to develop and evaluate effective language learning resources specifically tailored for LCTLs like Irish. This objective was explored in depth through the research questions addressed in Chapters 3 and 6. Specifically, RQ3: **How can language learning pedagogy be incorporated into DGBLL and evaluated to support LCTLs?** addressed this goal, dividing the inquiry into two subquestions. The first subquestion, **RQ3.1: How can language learning pedagogy be integrated into DGBLL to support LCTLs?** was thoroughly examined in Chapter 3, emphasising the importance of aligning language learning pedagogy with game design. Meanwhile, **RQ3.2: How can the effectiveness of language learning pedagogy in DGBLL be evaluated for LCTLs?** was the focus of Chapter 6, detailing the evaluation process of the Cipher game. The study showcased how pedagogical principles were integrated into the development of Cipher, ensuring that the game not only engaged learners but also met educational standards and learning outcomes.

Objective 4: Integrating Cultural Approaches into CALL for Indigenous Languages

The final objective was to explore how cultural approaches could be integrated into CALL for indigenous languages, using the Irish language as a case study. This was the focus of Chapter 7, where **RQ4: How can cultural approaches be integrated into CALL for indigenous languages?** was examined. The subquestions **RQ4.1: How can existing indigenous language resources be repurposed for DGBLL** and **RQ4.2: How can the theory of reconnecting to the spirit of the language be applied to indigenous language learning through DGBLL in VR?** explored the practical application of repurposing existing indigenous language resources for DGBLL and applying the theory of reconnecting to the spirit of the language through VR. The research highlighted how incorporating elements of Irish folklore and mythology into the game environment not only supported language learning but also helped learners reconnect with their cultural heritage, thereby fostering a deeper, more meaningful engagement with the language.

In summary, this research has provided valuable insights into how creative approaches, cultural integration, technological advancements, and pedagogical alignment can collectively enhance the learning of LCTLs. The findings from the research questions revisited across the chapters underscore the potential of DGBLL as a powerful tool for supporting the revitalisation and preservation of LCTLs, particularly minoritised languages, through engaging, culturally rich, and technologically advanced language learning resources.

8.2 Findings

This research offers insights into the potential of DGBLL to re-energise and enhance the learning experience for LCTLs. The development and iterative refinement of the Cipher game series have demonstrated that DGBLL can successfully engage learners, foster cultural connections, and improve language skills through a learner-centred, culturally responsive, and technologically integrated approach.

Findings indicate that the Cipher game has been well-received by both students and teachers, with a significant number of participants expressing a preference for learning Irish through the game over traditional classroom methods. This positive feedback underscores the importance of incorporating engaging and enjoyable elements into language learning. The adaptability of the Cipher game framework to different languages and contexts further highlights its potential as a versatile tool for LCTL education.

The addition of VR to the Cipher series represents a novel advancement in DGBLL, offering a more immersive and culturally rich learning environment. By embedding language learning within culturally relevant narratives and VR landscapes, the game not only enhances language acquisition but also deepens learners' connection to the cultural and historical contexts of the language. This innovative approach paves the way for future research and development in educational technology, particularly in the context of language preservation and revitalisation.

The study also emphasises the importance of a multidisciplinary, co-creation approach in developing effective CALL resources. The collaboration of linguists, educators, game developers, AI and CALL experts was crucial in creating a game that is not only pedagogically sound but also engaging and accessible to a diverse range of learners. The incorporation of AI technologies, such as TTS and image generation, has further enhanced the game's inclusivity and depth, catering to learners with diverse needs, including those with dyslexia.

Moreover, the use of NLP tools in the development of Cipher: Faoi Gheasa has proven essential in ensuring the quality and suitability of the language content. These tools have facilitated the analysis and classification of texts by difficulty level, potentially enabling the game to dynamically adjust to the learner's proficiency, thereby maintaining an optimal challenge level and promoting effective learning.

The findings indicate that with thoughtful design and technological integration, DGBLL can improve language learning outcomes, especially in contexts where traditional methods have faced challenges in maintaining learner engagement and motivation. Overall, the research highlights the promising potential of combining gaming technology with CALL in creating effective language learning tools for LCTLs, while also integrating cultural elements that deepen learners' connections to the cultural contexts of the languages.

8.3 Limitations

This section discusses the limitations encountered throughout the research. These limitations highlight the challenges faced in developing DGBLL tools for low-resource and indigenous and suggest areas for future research and development. The initial design constraints of the Cipher game posed a challenge. The game was built upon an existing framework (i.e., original Cipher for English), which restricted the scope for innovative game mechanics that might have been more effective for language learning, particularly in the context of low-resource languages. Although cultural and linguistic adaptations were made, these were limited by the existing game structure, potentially affecting the depth of cultural integration.

Technical challenges were a recurring issue, particularly the scarcity of NLP tools for the Irish language. This technological gap made the development of language learning resources more complex and time-consuming, as bespoke tools had to be created or adapted. Additionally, the limited availability of comprehensive language resources, such as digital texts, constrained the content available for the game, affecting the richness and diversity of the learning materials. Furthermore, the NLP tools developed or adapted for this research were relatively rudimentary compared to those for major languages, due to the limited resources available for low-resource languages like Irish. This limitation impacted the accuracy and efficiency of text analysis within the game, potentially affecting the quality of the language learning experience. Moreover, the tools were specifically tailored for the Irish language, limiting their applicability to other low-resource languages without significant modifications.

The user experience study and learning evaluation conducted as part of this research also had its limitations. The study was primarily carried out in a single English-medium primary school, which may not fully represent the broader population of Irish language learners in primary education. This potential sampling bias, coupled with the short duration of the study, limits the ability to assess the long-term impact of the game on language learning outcomes. While feedback was positive, the research did not explore whether the game led to sustained language acquisition or improved proficiency over time. Furthermore, logistical challenges prevented the testing of the dyslexic version of the game with students who have dyslexia. Future research could address this gap by evaluating the game's effectiveness with this specific cohort to better understand its utility and impact.

Incorporating the theory of reconnecting to the spirit of language into the game design also presented challenges. While cultural elements were integrated into the game, the depth of this integration was constrained by the digital medium. Fully capturing the richness of cultural and linguistic heritage in a game format proved difficult, and some cultural nuances may have been oversimplified or lost. Additionally, the use of VR to enhance this cultural connection introduced accessibility issues, as VR technology is not widely available or affordable for all learners, potentially limiting the reach and impact of this approach.

Beyond these specific challenges, this research also faces broader limitations related to generalisability and resource intensity. The methodologies and findings are highly context-dependent, focusing specifically on the Irish language. As a result, the extent to which these approaches can be generalised to other low-resource languages or different educational contexts requires further research. Furthermore, the development of DGBLL tools for low-resource languages proved to be resource-intensive, requiring significant time, expertise, and technological support. This suggests that scaling this approach to other languages or contexts may be challenging without substantial investment. However, the project adheres to a language-independent principle. Even when certain components, such as NLP or TTS, cannot be adapted directly, manual processes can be employed as alternatives. This adaptability underscores our careful selection of technologies—ensuring that any indispensable technique is widely applicable across different languages. If a technique cannot be replaced or adapted for other languages, it would undermine the goal of maintaining language independence.

Lastly, this research is heavily reliant on the availability and functionality of specific technologies such as NLP tools and VR. Any limitations or failures in these technologies could significantly hinder the effectiveness of the language learning tools developed in this study.

These limitations underscore the complexities and challenges of developing effective educational technologies for low-resource and indigenous languages. While this research makes valuable contributions, addressing these limitations will be crucial for enhancing the applicability and impact of the developed tools in future work.

8.4 Future Research Directions

This section outlines future research directions and development plans. The following areas are identified as key priorities for further exploration and development.

Expanding the Application of DGBLL Tools to Other Languages and Educational Contexts

One of the promising directions for future research is the expansion of the DGBLL tools developed in this study to other low-resource and indigenous languages and diverse educational settings (e.g., Irish-medium schools). Building on the success of adapting the Cipher game for Irish, future research could aim to support a broader range of languages, particularly those like Irish. This will involve developing additional language modules (e.g., language materials stored in separate files that can be reconfigured within the game) and ensuring that the game framework remains adaptable to different linguistic and cultural contexts. The inclusion of more languages will enhance the tool's relevance and usability, making it a valuable resource for diverse language communities. Moreover, future research could continue to explore the long-term impacts of this research on language acquisition and learner engagement, particularly in different educational contexts. Additionally, further development and testing of the dyslexic version of Cipher will be crucial to ensure it meets the specific needs of students in classroom settings.

Enhancing Learning Experiences in VR

The integration of VR into language learning presents a unique opportunity to create immersive and culturally rich educational environments. Future research should focus on enhancing these VR learning experiences by refining the cultural elements integrated into the game and including an Irish language interface. This will not only deepen the cultural connection for Irish learners but also make the tools more accessible to Irish speakers.

Furthermore, future work will shift focus to secondary school students, particularly through further VR development. The transition from primary to secondary education presents new challenges and opportunities for language learning. VR's immersive capabilities can be leveraged to create more complex and engaging learning scenarios suitable for older students, thereby supporting the continued study of the Irish language in secondary education.

Implementing Stealth Assessment of Learning Effectiveness

Stealth assessment, which involves measuring learning outcomes seamlessly within the game environment, is a promising area for future research. By embedding assessment mechanisms into the gameplay, educators (e.g., teachers) can gain insights into learners' progress without disrupting the flow of the game. Future development should focus on integrating stealth assessment techniques into the Cipher game, enabling real-time evaluation of language acquisition and providing feedback to learners in a non-intrusive manner.

Further Learning Effectiveness Evaluation

The current learning assessment within the game has primarily focused on vocabulary acquisition. However, the game has a focus on reading skills. Future research could aim to expand the assessment to include other areas such as reading comprehension and writing proficiency. This broader evaluation will provide a more comprehensive understanding of the game's impact on overall language learning and identify areas for improvement.

Including Speaking and Improving Listening Focus in the Game

Currently, the game implements limited listening practice through TTS technology due to technological constraints, particularly in the context of low-resource languages like Irish. However, future work should explore the integration of speaking practice within the game, which would require the use of speech recognition technology. Although challenging, especially for low-resource languages, this enhancement could significantly improve the game's ability to support holistic language learning by including speaking and listening components.

Evaluating the Effectiveness of Cultural Approaches

The integration of the theory of reconnecting to the spirit of language into the game design has shown potential for enhancing learner engagement and cultural connection. However, more rigorous evaluation is needed to fully understand the effectiveness of these approaches. Future research could include longitudinal studies to assess how cultural elements impact language retention, motivation, and cultural identity over time. This will help refine the integration of cultural content and improve the overall effectiveness of the game as a language learning tool. 7. Testing the Adaptive Features of the Game for the ZPD The adaptive features of the Cipher game, which adjust the difficulty of tasks based on the learner's performance, are designed to align with the ZPD. Future research could test these adaptive mechanisms to ensure they effectively support learners at different proficiency levels. This includes integrating more stories into the game and evaluating how well the game adapts to individual learning paces, as well as whether it successfully challenges learners without causing frustration or disengagement.

Collaboration and Funding Opportunities

Discussions were held with An Chomhairle um Oideachas Gaeltachta agus Gaelscolaíochta (COGG), and the Department of Tourism, Culture, Arts, Gaeltacht, Sport and Media regarding funding applications to further develop this research, and and they have expressed interest in supporting its continued development.

In summary, future directions for this research involve expanding its scope to include more languages, enhancing the learning experience through advanced technologies, and rigorously evaluating the effectiveness of the tools developed. These efforts, supported by potential collaborations and funding, could lead to substantial advancements in CALL and have a lasting impact on language learning for LCTLs.

8.5 Closing Statement

In reflecting on this research journey, it becomes evident that the intersection of technology, language, and culture holds transformative potential for the teaching and learning of LCTLs, particularly for low-resource and indigenous languages. By integrating innovative technology frameworks with culturally rich content, this thesis has not only contributed to the field of CALL but also underscored the importance of preserving and revitalising indigenous languages in the digital age.

List of Publications

- **Liang Xu**, Elaine Uí Dhonnchadha, and Monica Ward. User experience study of "Cipher: Faoi Gheasa", a digital educational game for language learning and student engagement. In *Proceedings of the 2nd Workshop on Games Systems within the 13th ACM Multimedia Systems Conference*, pages 5–8, Athlone, Ireland, 2022.

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Appendix A

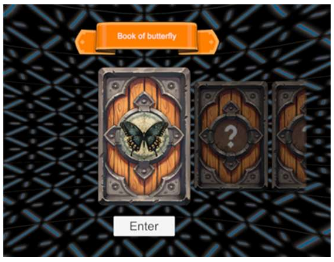
Plain Language Statement and Informed Consent

DUBLIN CITY UNIVERSITY
Plain Language Statement – Students

My name is Liang Xu and I am a PhD student in Dublin City University. I have a computer game called Cipher: Faoi Gheasa. It is fun to play and it may also help you improve your language skills.

In the game, you will be looking for ciphers (hidden clues) in encoded Irish stories. Your mission will be to discover errors in secret Irish messages. We will collect some data in the meantime. For example, the data tells us which errors are easiest to find. This data will also help to improve the game and the learning of Irish in the future. The data will be anonymous.

Here are some screenshots of the game:



If you volunteer to participate, I may ask you to play the game for 30 minutes. If you like the game, you are welcome to spend more time playing the game. You will be given a random username to play the game – it is anonymous (so I won't know who is playing the game). This helps to keep your game information secret. However, if you tell me something that is bothering you that has nothing to do with the game, I might have to pass on the information to someone else.

I will be very grateful if you would play the game but playing the game is entirely voluntary and anonymous. You can stop playing the game at any time. Your game data will be deleted once the research is finished.

This research is funded by the SFI Centre for Research Training in Digitally-Enhanced Reality (d-real).

If you have any questions about the game and want to talk to the researchers, please contact:
liang.xu6@mail.dcu.ie
monica.ward@dcu.ie

If participants have concerns about this study and wish to contact an independent person, please contact:

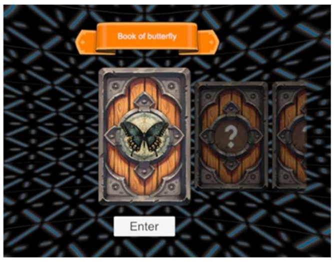
The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

DUBLIN CITY UNIVERSITY
Plain Language Statement – Parents

My name is Liang Xu and I am a PhD student in Dublin City University. I have designed a non-commercial computer game called Cipher: Faoi Gheasa. It is an interesting language game which will help your child improve Irish learning.

In the game, your child will be looking for ciphers (hidden clues) in encoded Irish stories. His/her mission will be to discover errors in secret Irish messages. We will collect some data during the game. For example, the data tells us which errors are easiest to find. This data will also help to improve the game and the learning of Irish in the future.

Here are some screenshots of the game:



If your child volunteers to participate, s/he will be asked to play the game for 30 minutes. If s/he likes the game, s/he is welcome to spend more time playing the game. Your child will be given a random username to play the game – it is anonymous. Any data generated in the game is confidential (subject to legal limitations). It is entirely voluntary and anonymous for your child to participate in the game, but if s/he does it will help Irish learning research. The signed consent form will be shredded once the research is complete. The school will be informed about the results when the project is completed.

This research is funded by the SFI Centre for Research Training in Digitally-Enhanced Reality (d-real).

If you have any queries and would like to contact the researchers, please contact:
liang.xu6@mail.dcu.ie
monica.ward@dcu.ie

If participants have concerns about this study and wish to contact an independent person, please contact:

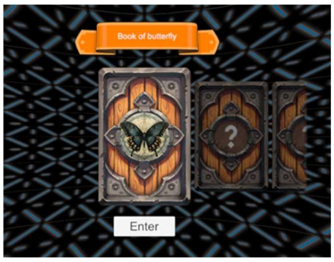
The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

DUBLIN CITY UNIVERSITY
Plain Language Statement – Principal/School Teacher

My name is Liang Xu and I am a PhD student in Dublin City University. I have designed a non-commercial computer game called Cipher: Faoi Gheasa. It is an interesting language game which will help the children improve Irish learning.

In the game, the child will be looking for ciphers (hidden clues) in encoded Irish stories. His/her mission will be to discover errors in secret Irish messages. We will collect some data during the game. For example, the data tells us which errors are easiest to find. This data will also help to improve the game and the learning of Irish in the future.

Here are some screenshots of the game:



If the children volunteer to participate, they will be asked to play the game for 30 minutes. If they like the game, they are welcome to spend more time playing the game. Your child will be given a random username to play the game – it is anonymous. Any data generated in the game is confidential (subject to legal limitations). It is entirely voluntary and anonymous for the children to participate in the game, but if they do it will help Irish learning research. The signed consent form will be shredded once the research is complete. The school will be informed about the results when the project is completed.

This research is funded by the SFI Centre for Research Training in Digitally-Enhanced Reality (d-real).

If you have any queries and would like to contact the researchers, please contact:
liang.xu6@mail.dcu.ie
monica.ward@dcu.ie

If participants have concerns about this study and wish to contact an independent person, please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Research and Innovation Support, Dublin City University, Dublin 9. Tel 01-7008000, e-mail rec@dcu.ie

DUBLIN CITY UNIVERSITY

Informed Assent Form - Children

Research Study Title
Cipher: Faoi Gheasa

Researchers:
Liang Xu, DCU School of Computing liang.xu6@mail.dcu.ie
Dr Monica Ward, DCU School of Computing monica.ward@dcu.ie

Purpose of the research

Learning a language can be boring sometimes but we have designed a game for you and we want to make this process interesting. The game is fun to play and hopefully will also improve your language skills. You can practise spelling, reading and writing in the game with interesting game tasks.

In the game, you will be looking for ciphers (hidden clues) in encoded Irish stories. Your mission will be to discover errors in secret Irish messages. We will collect some data during the game. For example, the data tells us which errors are easiest to find. This data will also help to improve the game and the learning of Irish in the future.
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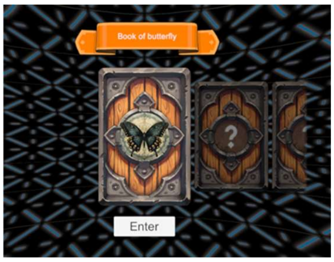


Student – please complete the following (Circle Yes or No for each question)

I have read the Plain Language Statement (or had it read to me)	*Yes/No*
I understand the information provided	*Yes/No*
I understand the information provided in relation to data protection	*Yes/No*
I have had an opportunity to ask questions and discuss this study	*Yes/No*
I have received satisfactory answers to all my questions	*Yes/No*

I know that I can withdraw from the Research Study at any point *Yes/No*

I know that I know the arrangements to be made to protect confidentiality of data, including that confidentiality of information provided is subject to legal limitations *Yes/No*
I know the arrangements regarding the retention / disposal of data *Yes/No*

If you have any questions about the game and want to talk to the researchers, please contact:
liang.xu6@mail.dcu.ie
monica.ward@dcu.ie

Signature:

I have read and understood the information in this form. My questions and concerns have been answered by the researchers, and I have a copy of this consent form. Therefore, I consent to take part in this research project

Student's Signature: ______________________________________

Name in Block Capitals: ______________________________________

Witness:______________________________________

Date:______________________________________

DUBLIN CITY UNIVERSITY

Informed Consent Form - Parents

Research Study Title
Cipher: Faoi Gheasa

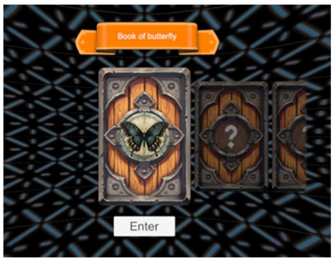
Researchers:
Liang Xu, DCU School of Computing liang.xu6@mail.dcu.ie
Dr Monica Ward, DCU School of Computing monica.ward@dcu.ie

Purpose of the research

The aim of this project is to gamify language tasks and make language learning more enjoyable. The game-based user interface, interesting game elements, and plots may motivate students to spend time in the game reading Irish text, comprehending it, and writing Irish text themselves. Moreover, the data collected in the study will help Irish learning research in the future.

In the game, your child will be looking for ciphers (hidden clues) in encoded Irish stories. His/her mission will be to discover errors in secret Irish messages. We will collect some data during the game. For example, the data tells us which errors are easiest to find. This data will also help to improve the game and the learning of Irish in the future.

Here are some screenshots of the game:



Confirmation of particular requirements as highlighted in the Plain Language Statement
Requirements may include involvement in interviews, completion of questionnaire, audio / video-taping of events etc.. Getting the participant to acknowledge requirements is preferable, e.g.

Participant – please complete the following (Circle Yes or No for each question)	
I have read the Plain Language Statement (or had it read to me)	*Yes/No*
I understand the information provided	*Yes/No*
I understand the information provided in relation to data protection	*Yes/No*
I have had an opportunity to ask questions and discuss this study	*Yes/No*
I have received satisfactory answers to all my questions	*Yes/No*

Confirmation that involvement in the Research Study is voluntary *Yes/No*
E.g. I may withdraw from the Research Study at any point.

Confirmation of arrangements to be made to protect confidentiality of data, including that confidentiality of information provided is subject to legal limitations *Yes/No*

Confirmation of arrangements regarding the retention / disposal of data *Yes/No*

Confirmations relating to any other relevant information as indicated in the PLS *Yes/No*
E.g. I consent to the use of my data for future studies within the following parameters (provide detail)

If you have any queries and would like to contact the researchers, please contact:
liang.xu6@mail.dcu.ie
monica.ward@dcu.ie

Signature:

I have read and understood the information in this form. My questions and concerns have been answered by the researchers, and I have a copy of this consent form. Therefore, I consent for my child _________________________ (insert child's name) to take part in this research project.

Parent's/Guardian's Signature: ___________________________________

Name in Block Capitals: ______________________________________

Witness:____

Date:____

DUBLIN CITY UNIVERSITY

Informed Consent Form - Principal

Research Study Title
Cipher: Faoi Gheasa

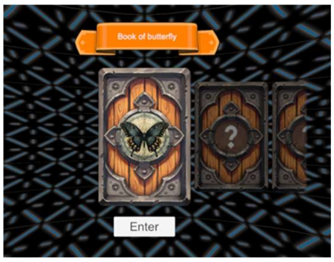
Researchers:
Liang Xu, DCU School of Computing liang.xu6@mail.dcu.ie
Dr Monica Ward, DCU School of Computing monica.ward@dcu.ie

Purpose of the research

The aim of this project is to gamify language tasks and make language learning more enjoyable. The game-based user interface, interesting game elements, and plots may motivate students to spend time in the game reading Irish text, comprehending it, and writing Irish text themselves. Moreover, the data collected in the study will help Irish learning research in the future.

In the game, the child will be looking for ciphers (hidden clues) in encoded Irish stories. His/her mission will be to discover errors in secret Irish messages. We will collect some data in the meantime. For example, the data tells us which errors are easiest to find. This data will also help to improve the game and the learning of Irish in the future.

Here are some screenshots of the game:



Confirmation of particular requirements as highlighted in the Plain Language Statement
Requirements may include involvement in interviews, completion of questionnaire, audio / video-taping of events etc.. Getting the participant to acknowledge requirements is preferable, e.g.

Participant – please complete the following (Circle Yes or No for each question)
I have read the Plain Language Statement (or had it read to me) *Yes/No*
I understand the information provided *Yes/No*
I understand the information provided in relation to data protection *Yes/No*
I have had an opportunity to ask questions and discuss this study *Yes/No*
I have received satisfactory answers to all my questions *Yes/No*

Confirmation that involvement in the Research Study is voluntary *Yes/No*
E.g. I may withdraw from the Research Study at any point.

Confirmation of arrangements to be made to protect confidentiality of data, including that confidentiality of information provided is subject to legal limitations *Yes/No*

Confirmation of arrangements regarding the retention / disposal of data *Yes/No*

Confirmations relating to any other relevant information as indicated in the PLS *Yes/No*
E.g. I consent to the use of my data for future studies within the following parameters (provide detail)

If you have any queries and would like to contact the researchers, please contact:
liang.xu6@mail.dcu.ie
monica.ward@dcu.ie

Signature:

I have read and understood the information in this form. My questions and concerns have been answered by the researchers, and I have a copy of this consent form. Therefore, I consent to take part in this research project

Principal's Signature: ____________________________________

Name in Block Capitals: ____________________________________

Witness:____________________________________

Date:____________________________________

DUBLIN CITY UNIVERSITY

Informed Consent Form - School Teacher

Research Study Title
Cipher: Faoi Gheasa

Researchers:
Liang Xu, DCU School of Computing liang.xu6@mail.dcu.ie
Dr Monica Ward, DCU School of Computing monica.ward@dcu.ie

Purpose of the research

The aim of this project is to gamify language tasks and make language learning more enjoyable. The game-based user interface, interesting game elements, and plots may motivate students to spend time in the game reading Irish text, comprehending it, and writing Irish text themselves. Moreover, the data collected in the study will help Irish learning research in the future.

Confirmation of particular requirements as highlighted in the Plain Language Statement
Requirements may include involvement in interviews, completion of questionnaire, audio / video-taping of events etc.. Getting the participant to acknowledge requirements is preferable, e.g.

Participant – please complete the following (Circle Yes or No for each question)	
I have read the Plain Language Statement (or had it read to me)	*Yes/No*
I understand the information provided	*Yes/No*
I understand the information provided in relation to data protection	*Yes/No*
I have had an opportunity to ask questions and discuss this study	*Yes/No*
I have received satisfactory answers to all my questions	*Yes/No*

Confirmation that involvement in the Research Study is voluntary
E.g. I may withdraw from the Research Study at any point. *Yes/No*

Confirmation of arrangements to be made to protect confidentiality of data, including that confidentiality of information provided is subject to legal limitations *Yes/No*

Confirmation of arrangements regarding the retention / disposal of data
Yes/No
Confirmations relating to any other relevant information as indicated in the PLS *Yes/No*
E.g. I consent to the use of my data for future studies within the following parameters (provide detail)

If you have any queries and would like to contact the researchers, please contact:
liang.xu6@mail.dcu.ie
monica.ward@dcu.ie

<u>Signature:</u>

I have read and understood the information in this form. My questions and concerns have been answered by the researchers, and I have a copy of this consent form. Therefore, I consent to take part in this research project

School Teacher's Signature: ____

Name in Block Capitals: ____

Witness:____

Date:____

Appendix B

Survey Results Across Different Stages of Testing

User satisfaction is assessed using a Likert scale, with responses ranging from 1 (very negative), 2 (negative), 3 (neutral), 4 (positive), to 5 (very positive). The available survey options vary depending on the specific questions. For detailed information, please refer to the corresponding tables or bar charts.

B.1 Stage 2 - Post-Survey

Sample Size: 64

Year: 2022

See Figure B.1

Bar charts showing Likert-scale responses (1-5, red to green, very negative to very positive) for 18 questions in the post-game survey for the Cipher game at Stage 3, conducted in a primary boys' school.

B.2 Stage 3 - Post-Survey

Sample Size: 169

Year: 2023

See Figure B.2 Bar charts showing Likert-scale responses (1-5, red to green, very negative to very positive) for 12 questions in the post-game survey for the Cipher game at Stage 3, conducted in a primary boys' school.

B.3 Stage 4 - Pre-Survey

Sample Size: 44

Year: 2024

See Figure B.3 Bar charts showing Likert-scale responses (1-5, red to green, very negative to very positive) for 6 questions in the pre-game survey for the Cipher game at Stage 4, conducted in a primary boys' school.

B.4 Stage 4 - Post-Survey

Sample Size: 31

Year: 2024

See Figure B.4 Bar charts showing Likert-scale responses (1-5, red to green, very negative to very positive) for 13 questions in the post-game survey for the Cipher game at Stage 4, conducted in a primary boys' school.

B.5 Stage 5 - Post-Survey - 4th Grade Boys

Sample Size: 23

year: 2023

See Figure B.5 Bar charts showing Likert-scale responses (1-5, red to green, very negative to very positive) for 13 questions in the post-game survey for the Cipher game at Stage 5, based on responses from 4th-grade boys in a primary boys' school.

B.6 Stage 5 - Post Survey - 4th Grade Girls

Sample Size: 30

Year: 2023

See Figure B.6 Bar charts showing Likert-scale responses (1-5, red to green, very negative to very positive) for 13 questions in the post-game survey for the Cipher game at Stage 5, based on responses from 4th-grade girls in a primary girls' school.

B.7 Stage 5 - Post Survey - 5th Grade Girls

Sample Size: 32

Year: 2023

See Figure B.7 Bar charts showing Likert-scale responses (1-5, red to green, very negative to very positive) for 13 questions in the post-game survey for the Cipher game at Stage 5, based on responses from 5th-grade girls in a primary girls' school.

B.8 Stage 6 - VR Pre-Survey

Sample Size: 21

Year: 2024

See Figure B.8 Bar charts howing Likert-scale responses (1-5, red to green, very negative to very positive) for 8 questions in the pre-game survey for the VR version of the Cipher game.

B.9 Stage 6 - VR Post-Survey

Sample Size: 20

Year: 2024

See Figure B.9 Bar charts howing Likert-scale responses (1-5, red to green, very negative to very positive) for 15 questions in the post-game survey for the VR version of the Cipher game.

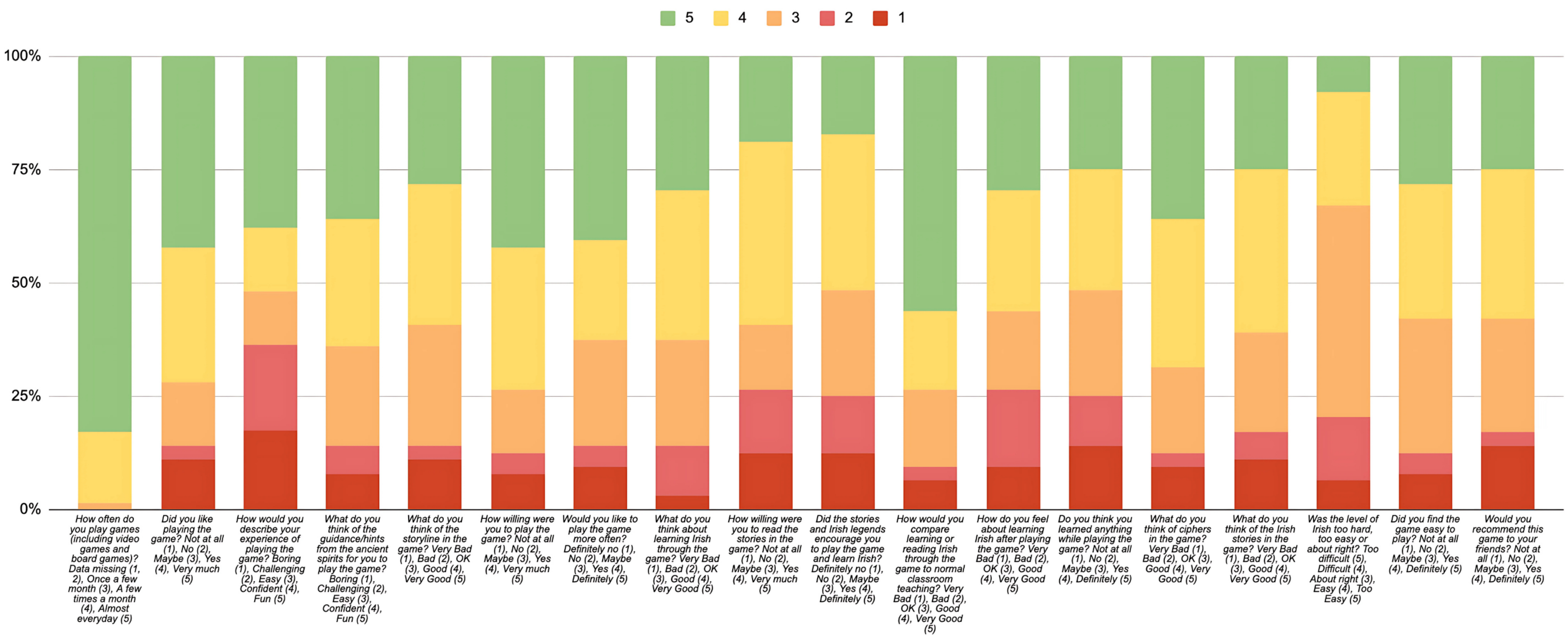


Figure B.1: Post-survey results at stage 2.

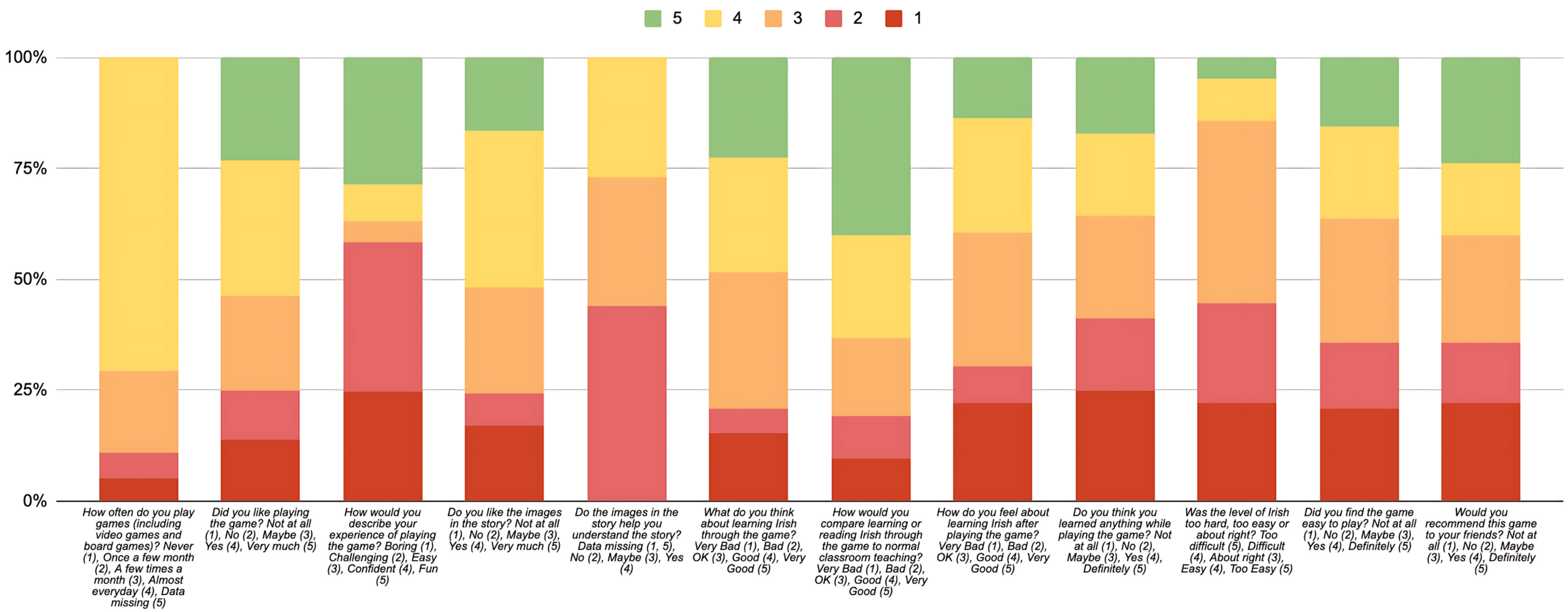


Figure B.2: Post-survey results at stage 3.

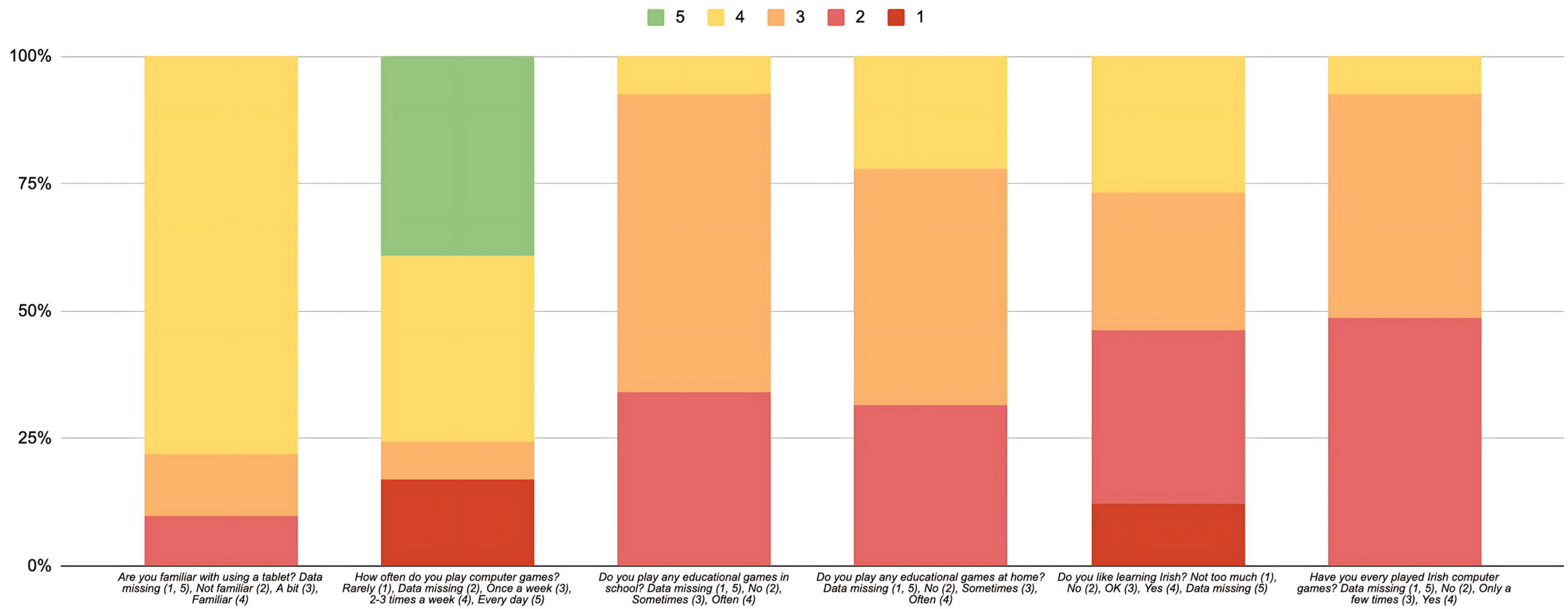


Figure B.3: Pre-survey results at stage 4.

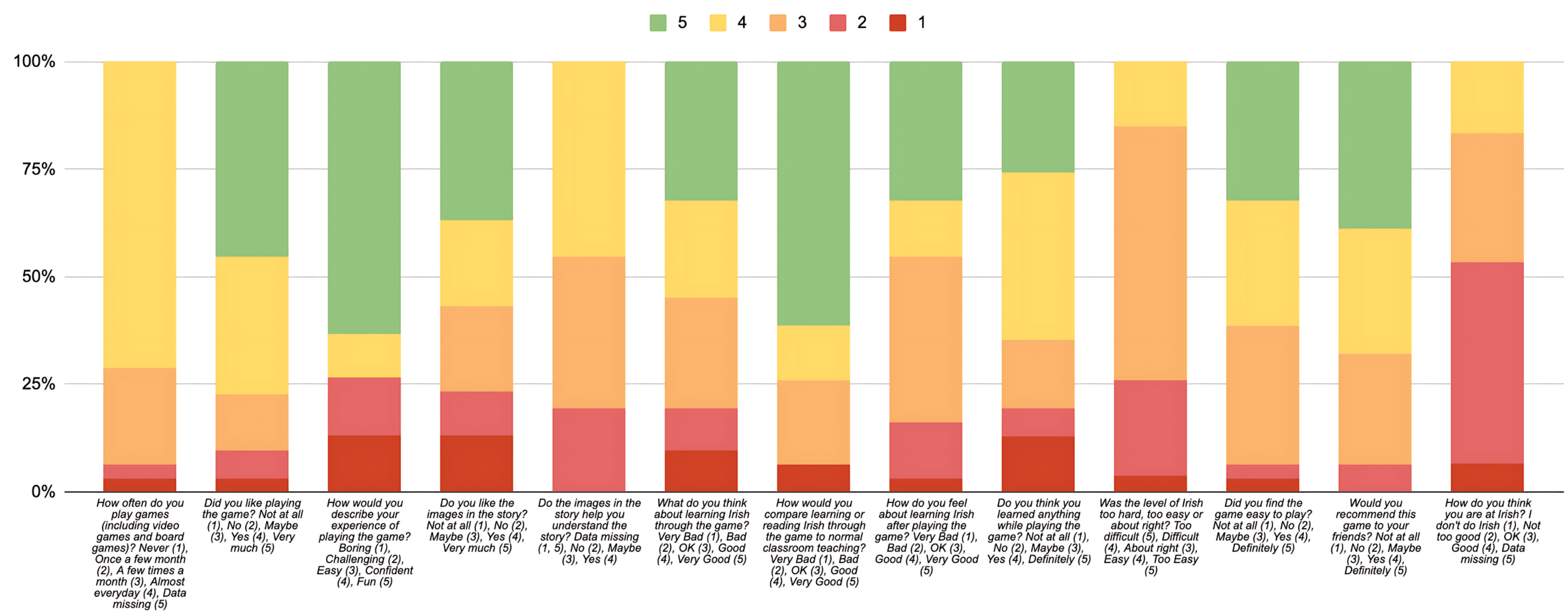


Figure B.4: Post-survey results at stage 4.

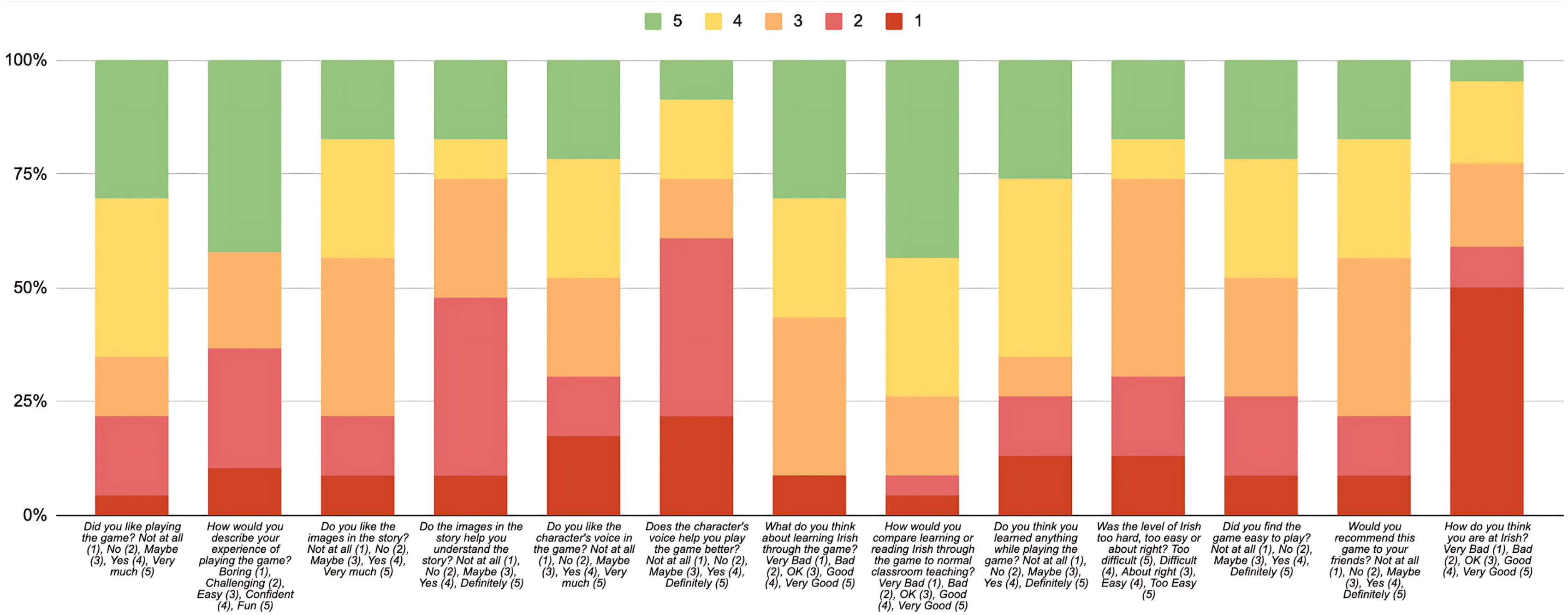


Figure B.5: Post-survey results of 4th-grade boys at stage 5.

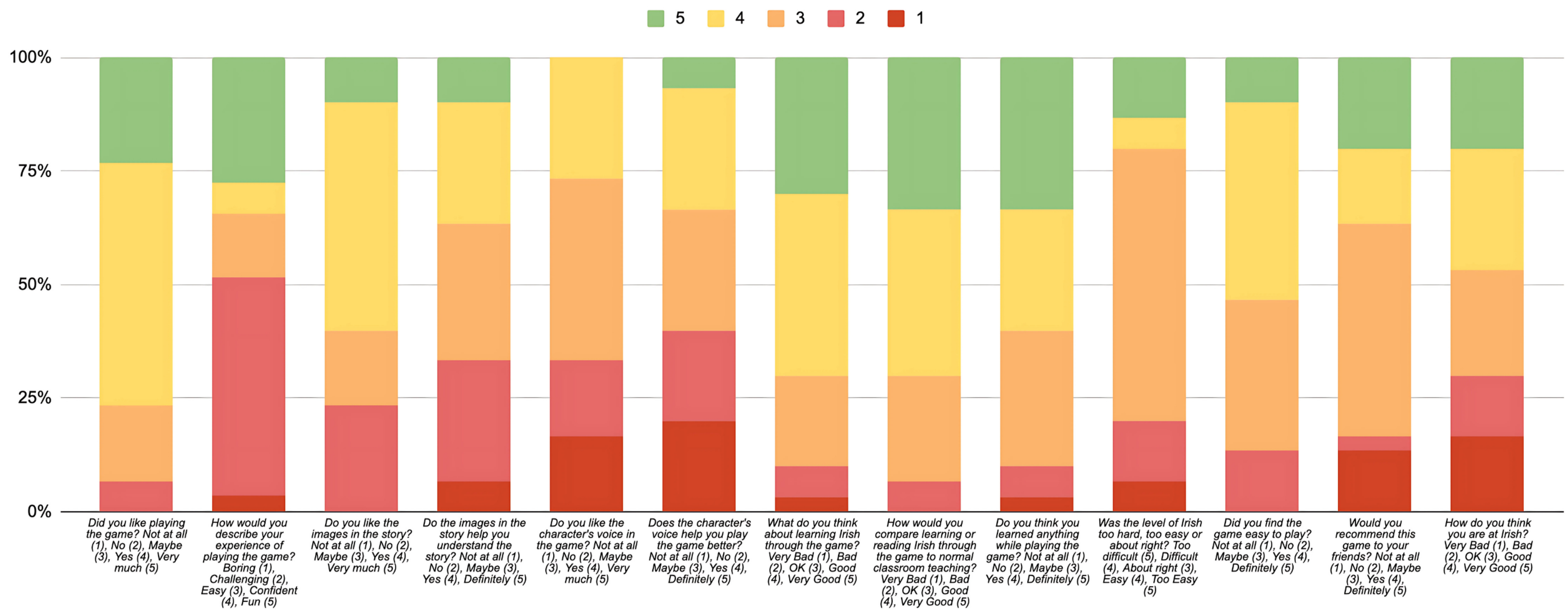


Figure B.6: Post-survey results of 4th-grade girls at stage 5.

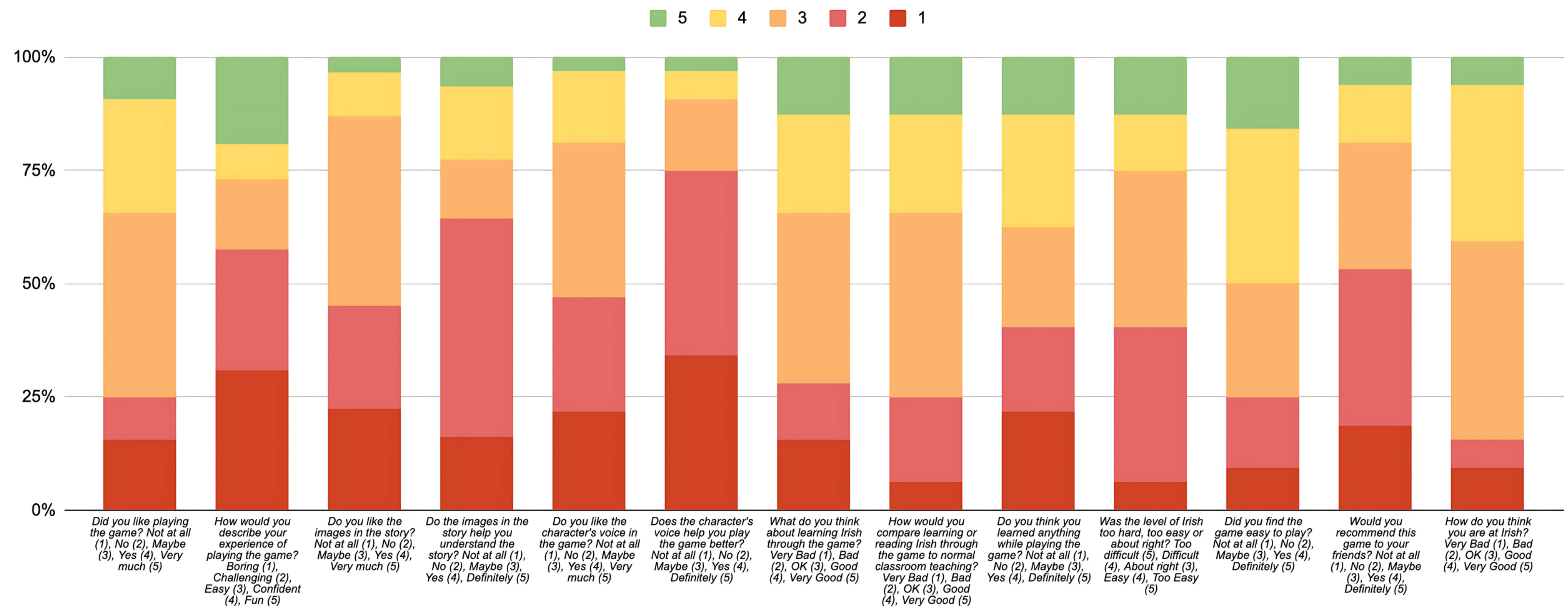


Figure B.7: Post-survey results of 5th-grade girls at stage 5.

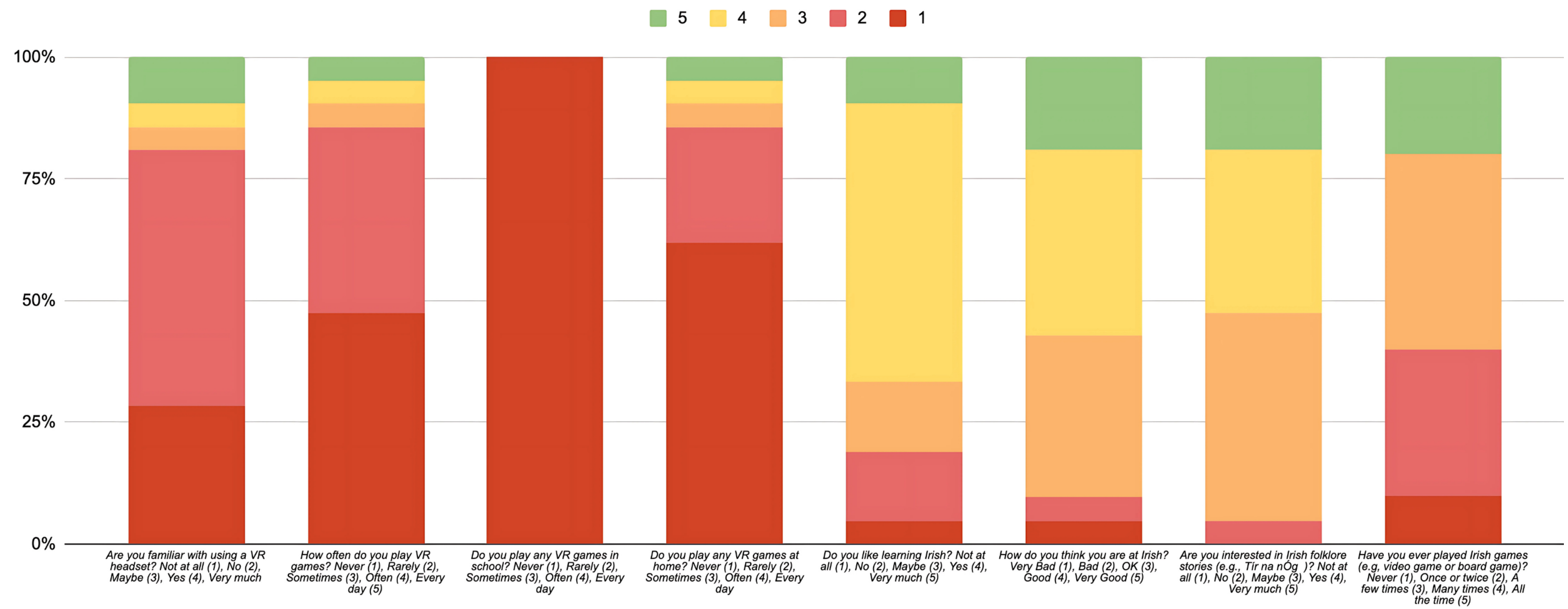


Figure B.8: Pre-survey results at stage 6.

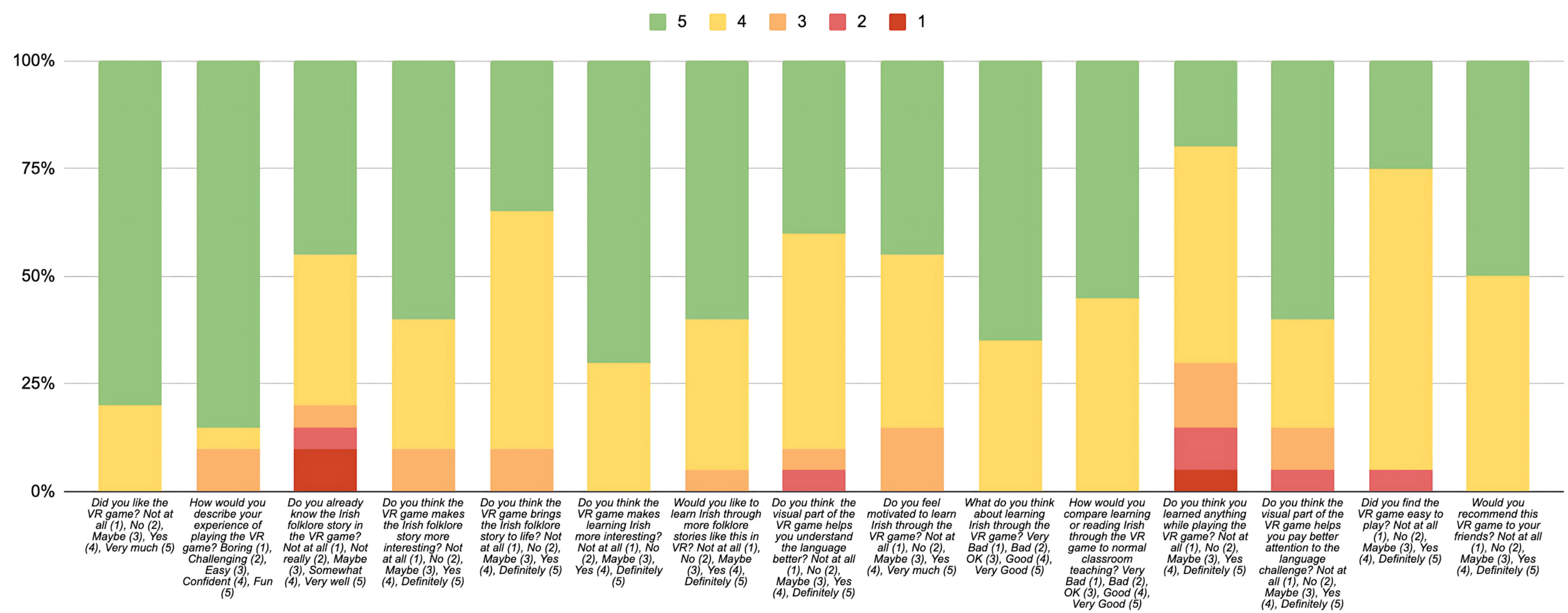


Figure B.9: Post-survey results at stage 6.