A Pragmatic Approach to Using Artificial Intelligence and Virtual Reality in Digital Game-Based Language Learning

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Abstract

Computer Assisted Language Learning (CALL) applications have many benefits for language learning. However, they can be difficult to develop for low-resource languages such as Irish and the other Celtic languages. It can be difficult to assemble the multidisciplinary team needed to develop CALL resources and there are fewer language resources available for the language. This paper provides an overview of a pragmatic approach to using Artificial Intelligence (AI) and Virtual Reality (VR) in developing a digital game-based language learning (DGBLL) app for Irish. This pragmatic approach was used to develop Cipher - a DGBLL app for Irish (Xu et al, 2022b) where a number of existing resources including text repositories and NLP tools were used. In this paper the focus is on the incorporation of Artificial Intelligence (AI) technologies including AI image generation, text-to-speech (TTS) and Virtual Reality (VR), in a pedagogically informed manner to support language learning in a way that is both challenging and enjoyable. Cipher has been designed to be language independent and can be adapted for various cohorts of learners and for other languages. Cipher has been played and tested in a number of schools in Dublin and the feedback from teachers and students has been very positive. This paper outlines how AI and VR technologies have been utilised in Cipher and how it could be adapted to other Celtic languages and low-resource languages in general.

1 Introduction

Computer-Assisted Language Learning (CALL) can be beneficial for language learners (Beatty, 2013). It can enable them to learn a language, either independently or in conjunction with a teacher. CALL resources can be used anytime and anywhere and at any pace. Using CALL resources can increase motivation for learners, enable them to repeat activities as often as they like and there is an element of privacy, so learners feel less inhibited about making mistakes. Learners of all language can benefit from using CALL resources. However, not all language learners have access to good quality, engaging CALL resources. There is a wealth of resources available for the world's most commonly taught languages, particularly English, but this is not the case for Less Commonly Taught Languages (LCTLs) such as Irish (Ward, 2016) and other Celtic languages. There are many reasons for this, including the difficulty of gathering a multidisciplinary team for the development of CALL resources and the lack of language technologies available for LCTLs (Ward, 2015a).

This paper focuses on a pragmatic approach to the development of Cipher, a CALL resource for Irish that combines several Artificial Intelligence (AI) technologies and VR to produce an engaging digital game-based language learning app for the Irish language. With limited resources available, it is important to use AI technologies and VR in a targeted and pedagogically sound manner to enhance specific elements of the app.

The Cipher app focuses on building vocabulary and reading. It is a game in which players have to find words in a story that have been put under a magic spell by an evil character and they must identify which spell the evil character has used. Players get points as they progress through the game and hints are available if necessary. The player is presented with various challenges that require them to notice spelling and word order. Although the main aim is to assist in language learning, the fun aspect of playing a game is paramount at all times.

This paper provides an overview of the technologies used in the app, which include NLP tools to assess the quality and level of the texts used in the game, text-to-speech (TTS) tools to provide audio for the game, the AI-image generation tool to produce images for the game and the VR tool used to produce an initial 3D version of the game. While this paper focuses on the Irish language version of Cipher, the game engine is language independent, and the app could be customised for other languages.

2 Background

2.1 CALL for Irish

The development of CALL resources for any language is difficult. Ideally, the CALL development team will be a multidisciplinary one with language teachers, linguists, software developers, user interface designers, Natural Language Processing (NLP) specialists and learners all being members of the team. Ideally, there will be a wealth of digital resources for the language, including texts, audio resources and NLP tools for the language. However, in the case of LCTLs, which includes all the Celtic languages, these ideal conditions do not prevail. It can be very difficult to assemble a multidisciplinary team and there are fewer digital resources for the language. In this scenario, it is really important to work strategically and to leverage existing resources for the language and to repurpose existing resources for other languages in the development of CALL resources for the language (Ward, 2015b). Each language has a different profile of resources available for CALL development. In the case of Irish there were a number of important resources that we were able to draw on. There is a collection of digital texts in the Dúchas.ie Schools Collection archive. This is a collection of folklore materials that were written by primary school children aged 12-14 in the 1930's. There is abair.ie, a high quality text-to-speech (TTS) tool for Irish that can produce audio files in three dialects and at varying speeds, which is particularly useful for language learning. There is a comprehensive morphological analyser and generator, and rule-based part-of-speech tagger (Uí Dhonnchadha & Van Genabith, 2006) that provides the grammatical features of words in the stories that are necessary for some of the ciphers (spells). Compared with better resourced languages, these resources do not provide the same coverage, but they have been very useful for the development of CALL resources for the language. These language-specific resources are now being combined with general-purpose AI language technologies to produce a more rounded application as will be outlined in the rest of the paper.

2.2 AI Technologies and CALL

AI has been discussed in the CALL research community for many years (e.g. Schulze, 2008; Ward, 2017). Natural Language Processing (NLP) technologies can contribute greatly to the development of CALL resources. NLP tools can be used in error checkers (including spelling and grammar checkers). They can be used to provide dictionary information for words and phrases in a text. They can be used to check the complexity of a piece of text in terms of lexical and grammatical complexity and this can be used to determine the suitability of a text for a given learner level. Bryant et al., (2023) provide a comprehensive overview of the use of NLP technologies in error correction. Gillespie (2020) charts the use of NLP in CALL research. To date, the use of AI technologies in CALL was relatively limited, but as the technologies have improved and become more accessible for non-AI experts, they are being increasingly used in the development of CALL resources.

Text to Speech (TTS) tools convert digital text into audio format. This can be really helpful in the language learning process, particularly if the language being studied uses a different writing system or orthography than the learner's first language (L1). While Irish uses the Latin alphabet, the orthography of Irish is different from English and this can be challenging for learners who tend to transfer their understanding of English orthography to Irish phonology. A further difficulty is that until recently, Irish orthography has not been explicitly explained to learners (in many primary and secondary school settings), and this makes it hard for students to read a word and understand how it is pronounced. Being able to read and hear a word pronounced can be really helpful for students.

Images can help in the comprehension of a text (Schroeder et al., 2011), especially if they are closely aligned with the content of the text. However, it can be challenging to find suitable images and it is expensive and time

consuming to design and draw images manually if suitable images cannot be found. One solution to this problem is to use AI generated images. Using AI generated images enables the CALL development team to create images that align with the text and create the desired atmosphere. For example, AI image generators can create images that are very realistic, cartoon-like or more ephemeral depending on what is required. The process of creating the desired image may not be entirely straightforward and care and thought are required to develop the prompts to the AI image generator in order to create the desired image.

2.3 Virtual Reality and CALL

Virtual Reality can help in the language learning process. Learners can be immersed in a virtual world where they can interact with the language. Being in a virtual world can help learners to forget their inhibitions about making mistakes and thereby overcome this barrier to learning a language. Another benefit of a VR learning environment is that the learner can 'be' in a world that does not exist in the real world. This could be a magical world or a world in the past or the future. These worlds can be exciting and engaging for learners, and CALL developers are starting to develop CALL resources using VR technologies.

2.4 Cipher: Faoi Gheasa - A Digital Game-Based Language Learning App for Irish

The main aims of this game are a) to increase user engagement and motivation for learning Irish, and b) to support the acquisition of Irish spelling, vocabulary and reading. We chose to use fiction, i.e., stories from folklore, mythology and traditional fairy tales, rather than non-fiction prose as it is more engaging for learners. The game is set in a magical world, where an evil character casts a spell on certain words in a text so that people will not be able to read and understand the text. These magic spells involve spelling the word backwards, swapping the first and last letter, doubling the last letter, or removing all vowels etc. The players have to find these enchanted words and identify which spell the evil character (Figure 5) has used on the words. This means that players have to pay close attention to words and to sound them in their heads. Initially we used a mix of real errors taken from primary school student writing, together with artificial errors such as spelling the words

backwards (spells). In our early testing it became apparent that real spelling errors were too difficult for learners to spot, whereas finding the artificial errors, because they were pattern-based, was much more achievable and enjoyable. We decided to use ciphers (spells) only and this has a number of benefits, including the fact that learners are not exposed to real errors. Also, we can develop spells that draw attention to language specific issues such as accented vowels, initial mutations and noun gender.

As players identify the spells and enchanted words, they gain points and progress to the next page in a story. Before players can progress to the story element of the game they must complete word challenges to become familiar with key words in the story and with the spells. Figure 1 shows a screenshot of a word challenge in the vocabulary priming element of the game where *ocras* (hunger) is under the *Méadú Guta* (Vowel Sprout) spell, all of the vowels have become accented vowels, while Figure 2 shows a screenshot of the main story element of the game, with some possible spells beneath. There is an example of a page from the Hansel and Gretel story where the highlighted words are under a spell. The player has identified 5 of the 6 enchanted words, and has correctly identified the *Cúl Faoi Dhó* (Double Tail) spell and incorrectly chosen *Iompú* (Reverse) in place of the correct *Tóin Aníos* (Bottom Up) spell.

Figure 1: Cipher Vocabulary.

3 Methodology

The core Cipher team consisted of a game developer, an Irish NLP researcher and a CALL researcher. Several other researchers and developers contributed to specific aspects of the project. While each member of the team had relevant expertise, it was important to leverage the affordances of AI and VR tools and technologies to

accelerate the game development process and enhance the game itself. A pragmatic approach was adopted whereby existing resources were reused or repurposed where possible and new tools were developed with limited, but targeted functionality.

Figure 2: Cipher Reading.

3.1 Integration of AI Technologies in Cipher

Children learn a language in a physical and cultural context and with all of their senses. In this CALL application the aim is to involve as many of the senses as possible to support second language learning. Sight is involved through the use of imagery, hearing through the use of audio support for vocabulary learning and to explain the rules of the game, and touch and motion through the Virtual Reality interface. Unique cultural heritage is invoked through the use of folklore and mythology in the stories and in the physical VR environment.

3.2 Text Content Development

Existing and new resources were used in the development of Cipher for Irish. Existing texts which were digitized as part of the Dúchas Schools Collection were the basis of some of the Cipher stories. While these stories are captivating, they were written before the introduction of the current standard orthography and grammar for Irish and had to be converted to the current standard, An Caighdeán Oifigiúil (Rannóg an Aistriúcháin, 2017). Existing NLP tools were used to tag each word in a text with its correct part-of-speech (POS) tag. This was important for implementing some ciphers which target or avoid specific types of words. Another use of NLP tools was in checking the suitability of texts for the target audience. Cipher is targeted at beginners and false beginners[1], although it can be adapted for more advanced learners as well. It was essential that the texts were at the appropriate level of difficulty for players so they could understand the texts and progress comfortably through the game. Readability tools and datasets are readily available for English e.g. the Flesch Kincaid (Kincaid, 1975), Gunning Fog (Gunning, 1952) and many more [2]. However, new NLP tools had to be developed for the purpose of rating Irish texts for readability. This involved creating appropriate datasets, and devising a text ranking formula by calculating lexical and grammatical complexity features, (Uí Dhonnchadha et al., 2024) as well as using AI learning (Mc Cahill et al., 2024).

3.3 Image Support

Text-to-Image generation i.e., Midjourney [3] was used to create the AI generated images. AI image generators can generate almost any kind of image and a less realistic, more cartoon like image theme was chosen for the Cipher game. This was in keeping with the overall vibe of the game. The AI image generator was also used to create the images for each page of the stories as well the vocabulary element of the game. Approximately 50-70 images per story were created. Some images were easy to generate, e.g. trees or a river, whereas more abstract concepts, e.g. in hiding, famous etc., were more difficult to conceptualise and took numerous attempts to find prompts that generated suitable images. Photoshop was necessary as a final step to fix aspects of some images or to remove unwanted items from images, such as a car parked outside the witch's house.

3.4 Audio Support

The abair.ie text-to-speech (TTS) tool for Irish, was used to provide the audio files for the vocabulary element of Cipher. The game has an English, Irish and Chinese interface. In order to make the game more accessible for learners, in the English interface, audio instructions were provided to players. The English language audio files were generated using a specific character voice from ElevenLabs [4]. The intention is to provide audio instruction in Irish as part of the Irish interface.

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[1] False beginners are learners who consider themselves to be beginners even though they already have some knowledge of the language.

This audio feature was added to reduce the cognitive load on players who may have difficulties reading the instructions as they can listen to them instead. The voice chosen for the instructions was witch-like, in keeping with the overall atmosphere of the game.

3.5 Integration of VR Technology in Cipher

The Cipher game is a 2D game that can be played on a tablet. However, a pilot 3D version of the vocabulary challenge element of the game has been developed to explore the use of VR technology in CALL for Irish. In the VR version of Cipher, the players still have to spell Irish words correctly to move through the game. Enchanted words from the Salmon of Knowledge story, appear in the magic book. The cipher is also given (see Fig. 3), which allows the player to mentally reconstruct the word, then they have to put the scrambled letters into the correct order on a table using their hands. This requires mental and physical activity. Meanwhile, the game is situated in the ancient mythical world of The Salmon of Knowledge. This variety of sensory input makes vocabulary learning more memorable. Unity[5] was used to develop the 3D version of Cipher and VR. Figure 3 shows a screenshot of the VR version of Cipher. It shows the word *tine* (fire) under the 'Vowel Sprout' (*Méadú Guta*) spell becoming 'tíné'.

Figure 3: Scrambled letters on a table and hand tracking in VR in an immersive folklore world.

3.6 Cipher Development Process

The initial version of Cipher was developed for English error correction and players had to select words that were spelt incorrectly in a text (Xu & Chamberlain, 2020). The Cipher team saw the potential of the game for language learning and decided to repurpose the game for Irish. This required finding and pre-processing Irish texts, the development of ciphers specific to Irish, and adding new game elements. The Irish version of Cipher taps into the 'spirit of the language' and is imbued with an ancient mythological Irish atmosphere. It has a vocabulary game at the start of each story, so that players can become familiar with key words in the text. There are AI-generated images and audio files to support the players. Hints are available to the players, but their points tally will decrease when they ask for help. If a player runs out of points, they can regain points by constructing a sentence using word bricks which will enable them to continue playing (Figure 4). A similar work brick approach was used successfully before with Irish (Purgina et al., 2017).

The Cipher development process is an iterative one. The core development team consisting of a game developer, an Irish NLP expert and a CALL developer, was supported by additional game developers, teachers and learners. When a new feature or improvement was added to the game, teachers and learners provided feedback which was used to inform the next development cycle of Cipher.
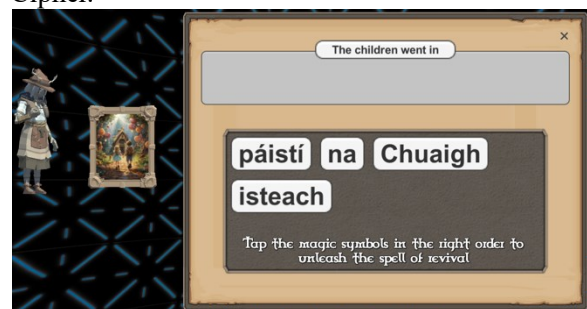

Figure 4: Sentence word bricks for Cipher.

Figure 5 An evil spirit

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[5] https://unity.com

4 Results and Discussion

The Cipher game was positively received by students who preferred it over traditional classroom methods in a school-based survey (Xu et al., 2022a; Xu et al., 2024b). User feedback indicated a high level of satisfaction, with participants finding the game engaging and enjoyable, aligning well with their learning needs (Xu et al., 2022a). Cultural integration and responsive design elements within Cipher also contribute to its success as a language learning tool, with features like AI-generated visuals and VR increasing comprehension and immersion (Xu et al, 2023; Xu et al., 2024b). Cipher demonstrated learning gains in vocabulary acquisition, which was measured through the use of a double-baseline study involving approximately 60 primary students (Xu et al, 2024a).

There are several factors that contribute to the success of Cipher. These include adapting an existing resource (Cipher for English), the use of existing digital resources (e.g. Dúchas Schools Collection), the use of existing NLP resources (e.g. abair.ie, Irish morphological analyser), the development of new NLP tools (e.g. text readability tools for Irish) and the use of new AI technologies (e.g. AI-image generator, VR development toolkit).

Other factors include a modular approach and designing in a language-independent framework from the outset of the development process. This meant that changes could be made relatively easily and in an incremental manner. This iterative approach, which aligns with the agile approach to software development, is particularly suitable for contexts where there are a lot of unknown elements, which is true in the context of Cipher, where technology and the practicalities of a school setting must balance. The language-independent aspect means that it was easy to change the interface language, as well as the target language being studied. For example, an English interface is used for the instructions in the English-medium schools, with Irish being the interface language for the Irish-medium school.

Another important factor was the co-creation approach adopted by the Cipher team. This involved working with teachers and learners on a continuous basis throughout the development process. The teachers were able to help in selecting the words for the learning enhancement experiment and to give feedback on the Cipher game itself. The learners also seemed honest in their feedback, especially when there were parts they did not like. Their feedback was very helpful for the development team. The iterative and co-creation approach helped make Cipher an inclusive and resonant resource for Irish language acquisition.

It was relatively easy to use abair.ie and the elevenlabs.io TTS tool for the audio elements of Cipher. However, the other processes were less straightforward. The process of converting the Dúchas.ie texts to modern orthography (post 1958), and grammar conventions was semi-automated. While some of the conversions were straightforward (e.g., endings of verbs) and tools[6] are available to assist in the process, a manual post processing step was required to ensure the correctness of the conversion process. Currently there are approximately ten stories each with five to seven pages in the game.

The generation of the AI images while highly successful, was more time consuming than initially anticipated, as the prompts had to be carefully worded to ensure the creation of the desired images. AI image generators can generate images that reflect social biases and/or images that are inappropriate or weird. For example, asking the AI image generator to create images of witches led to images of very ugly women with warty notes or adult-themed images - neither type of image would have been suitable for primary school students. It was also challenging to ensure consistency of images across a story. Even something as straightforward as a boy and a girl, holding hands and walking in a wood was difficult (e.g. for Hansel and Gretel). Sometimes the images of the boy and the girl would not be consistent or the hands were not drawn correctly (hands are notoriously difficult for AI image generators). All images were pre-generated and vetted to ensure consistency and appropriateness, and in some cases Photoshop post-processing was necessary. Image creation has been carried out for two of the stories.

4.1 Limitations

There are several limitations that should be noted in the context of this paper. Firstly, the text,

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[6] The following tools can convert between varieties of Irish: https://github.com/kscanne/caighdean/blob /master/API.md and http://www.potafocal.com/cai/

audio and image content is limited, and a much larger bank of stories needs to be developed. Secondly, while it was good to test Cipher in several different classrooms, the limited number of schools (three) means that current findings cannot be extrapolated to a wider cohort of students. Future testing will be required to validate these findings on a wider scale. The findings to date are promising and it will be interesting to see if these can be replicated with different cohorts of students.

The VR version of Cipher is currently at the pilot stage and the development of a VR game is more difficult than that of a 2D game due to the inherently more difficult programming process. However, in anticipation of further 3D developments, the 2D version of the game has been designed with VR in mind. The positive feedback to date on the VR version has given the Cipher development team encouragement for further developments to the 3D version of Cipher (Xu, 2024b).

5 Conclusions

In terms of adapting Cipher for other languages, there are several approaches that could be taken. In terms of the game itself, the Cipher system could be used to develop Cipher for another Celtic language. There may be an existing digital corpus of stores for the language or existing printed texts may be used as inspiration for suitable stories for Cipher. If the CALL developers have access to a POS-tagger , xml pos-tagged texts could be added to the Cipher system and this would speed up the development process. If xml pos-tagged files are not available, suitable texts could be manually tagged as a workaround. In terms of the audio files, if a TTS generator is available for the target language, that would be beneficial. If not, human recordings can be used instead. There are many TTS tools available for use in generating instructions in English, French and other well-resourced languages if this is an appropriate interface language for the game. AI-image generators are readily available, and although there are usage limits on the free versions, it is still possible to use them to generate appropriate images for stories. The VR tools are widely available and could be used by developers in other language contexts. In short, the more digital and AI resources available for the language, the easier it would be to create a Cipher game for the

language. However, even if such resources do not exist, human-power can be used to generate a new version of Cipher for the language. Table 1 provides a summary of the resources reused, repurposed and developed as part of the development of Cipher, along with suggestions of how other languages could adopt a similar approach to the development of a Cipher version for the language.

Resource used	Existing/ Repurposed/ New	Comment
English language Cipher game	Repurposed	Could be repurposed for other languages
Dúchas collection	Existing and repurposed	Irish Folklore and culture focus
POS-tagger	Existing	An alternative would be a manually xml-tagged file
Readability tool	New	Semi-automatic
AI image generator	Existing	Language-independent, context aid
abair.ie	Existing	For Irish vocabulary pronunciation
English TTS tool	Existing	For in-game instructions
VR tool	Existing	Reinforce folklore and cultural immersion

Table 1: Overview of resources used in the development of Cipher

The integration of AI tools and technologies in the development of CALL resources for Irish can lead to the development of useful resources such as Cipher. Often CALL developers who work in the LCTL space can be intimidated by the challenge, but the approach adopted by the Cipher team demonstrates what is possible by using a combination of existing resources, development of new resources, along with a pragmatic and co-

creation approach. Researchers working with other Celtic languages are encouraged to adopt a similar approach. The Cipher team would be happy to collaborate with other Celtic language researchers in developing a version of Cipher for their own language.

Acknowledgements

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