# Towards Evidence-informed Design Principles for Adaptive Reading Games

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**ABSTRACT**

This demonstration presents the design principles of the Navigo games for young children's reading. By reflecting on our design tools and processes we explore the way theory, empirical evidence and practice have informed our game design. We look into the reciprocal role of theory and design and provide transferable lessons for design of educational technologies in the context of HCI.

**KEYWORDS**

Adaptive games; learning; design; theory


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Figure 1: Navigo Game

## 1 GAME DESIGN FOR LEARNING

Games for learning offer the potential to personalise and scaffold children's learning of different domain topics. Designing learning games, however, is not a straightforward process, and what instructional dimensions support the learning process has occupied both education and games design researchers alike. While theory has been long considered to be a critical input to design, in education technologies *evidence-based design* is a particularly dominant dimension [e.g. 3].

Over the past two years, the EU-funded iRead consortium has been designing a game that aims to support primary school children's reading skills. Our game "*Navigo: the Pyramid of the Lost Words*" (see Figure 1) has been motivated by the importance of literacy as a foundational skill with implications in lifelong learning. In Navigo the player takes on the role of a child whose grandmother is a world-renowned adventurer investigating a mysterious pyramid. On her request, the player travels to the desert but is caught in a sandstorm. It transpires that the player's grandmother, went into the pyramid to take shelter from the storm and it is down to the player to unlock its secrets through completing learning activities focused on different reading skills. The game incorporates 16 different mini-game mechanics, which have been designed for six areas: phonology, morphology, word recognition, orthography, syntax and morpho-syntax. As part of designing Navigo, we have created 1,000 instantiations of the 16 mini-game mechanics each practising a specific skill.

The goal of this demo is to showcase a number of Navigo game activities and how they are adaptively sequenced, while at the same time demonstrate our process to reflect on the *reciprocal* role of theory, empirical evidence and practice in educational technology design.

## 2 EVIDENCE INFORMED PEDAGOGICAL DESIGN PRINCIPLES

Our design work has been guided by a combination of learning theory, a critical evaluation of previous and our own empirical research, and user research through knowledge elicitation in what can be characterised as evidence-informed design [3]. We use the term 'informed' to highlight that diverse sources and types of evidence are used to support design decisions. This includes 'theory' in a sense similar to [4] i.e. the kind of theories that support us "in generating, selecting and validating design alternatives at the level at which they are consequential for learning".

Our initial point of departure was the literature on *learning and games*, that has been characterized as 'frameworks of action' in [4] i.e. theories that provide 'general prescriptions of pedagogical strategies'. In a 2018 CHI paper, we identified that instructional elaborative feedback, informing the child's understanding and supporting the child in overcoming a breakdown in their learning, is one of the most powerful interventions raising attainment. We analysed five commercial games for reading that are currently used in schools, finding that these games embedded principles that supported the child's understanding of feedback such as clear *learning aims*, *success criteria* and *initial instruction* of the learning content. However, we also discovered that these games rarely provided *elaborative feedback*, notifying the players on the correctness of their response rather than how to improve it [1].

| **Design principles for Navigo** |
| --- |
| DP1 Introduce clear success criteria and learning aims in each game |
| DP2 Offer elaborative game feedback when the child has a breakdown and deter the child from using trial and error strategies |
| DP3 Choose content that focuses on a single learning aim without introducing new, yet encountered language features |
| DP4 Introduce interleaved practice of language features to support better transferability |
| DP5 Facilitate a gradual move from understanding the basic unit of language to using it in context and then automatizing it |
| DP6 Discourage the concurrent introduction of new game mechanics and learning aims |
| DP7 Strike a balance between maintaining a good level of challenge and sense of efficacy |
| DP8 Reinforce previous learning of linguistic feature after a certain period of time |
| DP9 Provide data for teacher awareness and parent engagement and support to additionally scaffold learning. |

**Figure 1: Pedagogical design principles**

Having developed a critique on the design of existing commercial games we went on to carry out *empirical observational research* with these games exploring when and how young children overcome learning 'breakdowns' in the absence of elaborative feedback. In our 2019 CHI paper we showed that children were able to independently progress in these commercial games only less than half of the times they encountered a breakdown. When they did progress, they used a trial and error strategy which was highly mediated by the game mechanic. Trial and error was most prevalent when the game mechanic allowed children to find the correct answer through a process of elimination [2].

Alongside the broader engagement with games-based learning theories, we found necessary to employ *domain-specific instructional theories of reading*. These theories shed light into children's reading development allowing us to specify the characteristics of language that children should encounter at the different stages of their learning. For example, we identified that the words and sentence constructions encountered by children should focus on a single learning aim, with non-encountered language constructions taught and practised separately. Engagement with these domain theories was also critical in making design decisions about which of the 16 mini-game mechanics to prioritise in gameplay, and which language feature to choose from when sequencing games. For example, we identified the importance of diversified learning across different learning areas, and the learning progression from knowing a language rule to applying it and finally automatizing it.

However, as others have recognised [4], even domain-specific theories can often be too vague and complex to operationalise, or too specific and non-transferable particularly when the design of a system itself, the tasks that it affords, and the relationship between the environment and the knowledge domain co-evolve. The latter is particularly the case in the design of adaptivity components. We thus found it necessary to engage in co-design in the form of 'knowledge elicitation' with experts (teachers and linguists) to invent, discuss and iterate over the rules that inform the selection of the language features, the game content, and the design of the game mechanics.

Figure 1 summarises the design principles that resulted from our literature review, empirical research and co-design, guiding our overall game design. Tables 1 and 2 show examples of how some of these design principles were married with the technical language operationalizing the games.

## 3 DEMONSTRATION

The main aim of our demo is to showcase the design principles and how they are operationalised in our context as follows.

**Demonstrate games for the six reading skills**: we will show six mini-game mechanics with learning aims belonging to the six diverse reading skills in Navigo. Through this, we will evidence the use of different game mechanics across language areas showing the scaling up of our approach. In doing so, we will show the connection between our evidence-informed design and the game outcomes.

| **Design principle** | DP1, DP2, DP3 |
|---|---|
| **Language feature under the phonology skill** | /s/s |
| **Learning aims** | Select the word that starts with s |
| **Success criteria** | Four out of five responses |
| **Elaborative feedback** | Words like sad, start with s |
| **Restrictions on correct response content** | Maximum word length: 4 characters; Position of feature: start; Prefix: none; Suffix: none |
| **Restrictions on distractor content** | Maximum word length: 4 characters; Position of feature: start; Prefix: none; Suffix: none |

**Table 1: Game design specification of a Navigo game mechanic**

| **Design principle** | DP4 |
|---|---|
| **If** | Features from multiple language categories are available |
| **Then** | Order the features selected as follows: (1) select up to 3 features from the same category (2) then move to the next category (3) repeat |

**Table 2: Adaptivity rule that directs the game to choose a learning aim**

**Demonstrate sequencing of games for the six reading skills**: we will play through a small set of language features to demonstrate how the adaptivity component relies on the language domain and child's user model to sequence games by selecting appropriate features, content and game mechanics providing the children with mastery opportunities.

## 3 RELEVANCE TO THE CHI COMMUNITY

The iRead project aligns with an aspirational and value-oriented view of design in HCI. We address a global and societal need to support the development of reading skills to children in primary school for both developing readers aged 5-8 as well as older children with dyslexia. Of relevance to HCI, we will show the design representations and tools generated from our aim to design an evidence-informed game, discuss some of the strengths and challenges in using the tools, and reflect on the facilitative role of these tool in making some of the, otherwise implicit, decisions and knowledge more explicit across project members. This has allowed us to work together to connect pedagogical and technological expertise. Such reflections provide transferable lessons for design of educational technologies from an HCI perspective. Finally, the interplay of theory and design is of core interest to CHI researchers and practitioners and the demo of the specific instructional dimensions of the games and their adaptivity will also enable us to share insights from early trials that further validate, challenge or advance domain theories. In doing so, we will contribute to the on-going debate in CHI about the role of theory in design, and the role of design in further developing theory.

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