# CURIO: A Game-Based Learning Toolkit for Fostering Curiosity

Marcello A. Gómez Maureira
Leiden Institute of Advanced Computer Science
Leiden, The Netherlands
m.a.gomez.maureira@liacs.leidenuniv.nl

## ABSTRACT

Curiosity is an important motivator to facilitate learning in all aspects of life, including formal education. Digital games stand out among the methods that can be used to invoke curiosity by providing an interactive, yet controlled environment. In this paper we present the conceptual design for CURIO, a multi-user classroom game that seeks to invoke curiosity through its gameplay. We describe a series of three focus groups with educators, conducted with the purpose of determining what requirements such a game needs to fulfill. On this basis we have developed a conceptual game design that will be further evaluated and modified through future test sessions.

## CCS CONCEPTS

• **Applied computing → Computer games**;

## KEYWORDS

Curiosity, Game-Based Learning, Game design, Serious Games

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## 1 INTRODUCTION

Children are masters at acquiring new information. Unfamiliar languages quickly become natural tools for conversation, and the most minute details are easily memorized when there is the motivation to do so. As children enter the formal education system however, there is an increasing demand to learn about topics that they might not be naturally interested in. In the past, students were expected to accept this as a reality of education and work-life in general. However, modern teaching methods recognize the importance of invoking the curiosity of students to support a more in-depth understanding of what is being taught and tested. Students who are curious about a topic are more motivated to seek out related information on their own, and thus take an active approach to learning.

In this paper we discuss the concept development of **CURIO, an educational game for classroom use that aims to invoke curiosity as part of its gameplay**. CURIO is designed to be played by multiple students in a classroom and a teacher that acts as a guide within the game environment. Students use tablets to play the game and share a virtual space in which they are tasked with answering exam questions. These can be answered through text input or by taking pictures with their tablets. Progress in the game is, however, not achieved by correctly answering such questions, but rather by posing new questions about the answers that students have come up with. Teachers can then use these questions as points of departure for their lectures and classroom discussions. As such, CURIO is designed to promote an inquisitive mindset in students, and to stimulate the active involvement of teachers in an educational game.

While this paper focuses on the conceptual design of CURIO, it also discusses the requirements that the game has to fulfill. CURIO was designed to meet the needs of Maltese classrooms and was funded to improve students' performance in STEM fields. The use of digital games to support learning is anything but new, but still remains a challenge. Especially within the classroom, an educational game has to provide meaningful interaction that supports learning, but also take into account the context in which the game is played. In an effort to overcome these challenges, we discuss prior work in the area of game-based learning and research into curiosity. This is followed by a report of focus group discussions with educators. With the insights gained from these consultations, we describe the game design of CURIO in more detail, as well as how the individual design aspects support the goals of this project. As project development continues, we will test the assumptions that are made in this paper, and modify the design of the game where necessary.

## 2 RELATED WORK

Both in its aim to invoke curiosity, as well as in the context in which it is designed to be used, CURIO is a 'serious game'. This term refers to games that are designed with a purpose other than entertainment, although entertainment does remain a factor that needs to be balanced against other requirements [15, 28]. Serious games are developed for many fields, such as medical or military training, therapy, or education [4]. The latter is studied under the label of Game-based Learning (GBL), referring to games that are dedicated to facilitate the transfer of knowledge and learning [1]. GBL promises to motivate players through commonly used game elements, such as involving a clearly defined goal, providing rewards, and delivering frequent feedback [14]. The interactivity offered in games can further support the understanding of subject matter based on experimentation instead of relying on passive absorption of knowledge [16]. While GBL has known potential, the development of educational games remains a challenge. Aside of ensuring


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technical functionality and meeting the expected level of audio-visual fidelity, they must have a demonstrable impact on a player's educational progress. The example of *Ludwig*, an educational game created to teach students about renewable energy production in the classroom, serves as a case study that successfully afforded the transfer of knowledge [32]. At the same time, the authors note that the learning progress required the active involvement of teachers: "Classroom learning, in particular at the elementary and middle school levels, is driven by the interaction between the teacher and the students" [32]. This is noteworthy, as the design of *Ludwig* does not specifically address the involvement of a teacher or the use within the classroom. Despite this, the authors note that it succeeded in making students curious and motivated them to learn.

The connection between curiosity and the resulting action of seeking out new knowledge is what makes curiosity an important aspect of education [26]. Research into curiosity comes predominantly from the fields of philosophy [11, 29] and psychology [3, 8], leading to different perspectives on what curiosity is and how it occurs. For our research project, we understand curiosity as the intrinsic motivation for pursuing new knowledge and experiences that is accompanied by pleasure and excitement [10]. This view is informed by studies from both research domains, and places equal importance on the motivation for action and the feeling that is experienced as part of it. The question of how curiosity occurs requires further elaboration, such as whether it occurs as an 'in-the-moment' state [22], or whether it is discussed as an individual's overall tendency to become curious, referred to as 'trait curiosity' [21]. In our research project we are primarily interested in invoking curiosity as a result of a purposeful intervention. As such, we aim to invoke 'state curiosity'. However, studies have shown an influential relationship between state and trait curiosity [13, 19, 27], suggesting that research results from studies exploring trait curiosity may still be relevant for our project. Most of the existing work in quantifying curiosity - arguably a necessity for any effort to invoke it demonstrably - is concerned with measuring trait curiosity [18, 20] or related personality traits, such as intrinsic motivation [6, 23] or sensation seeking [34]. There have also been efforts to measure the state of curiosity, including the use of games as research instruments. In one such a study, the performance of players within an exploration game was used as a behavioral measure for state curiosity [12].

Curiosity and games overlap in a variety of ways, whether games are the instrument for invoking it, or whether it is studied as an affective component in gameplay. This overlap should be expected, as curiosity has been described as being of central importance for play [31]. While relatively few research papers directly explore curiosity in games, related concepts such as uncertainty [5] and player engagement [30] have been studied in more detail. Such studies provide context-dependent insights, thus complementing more general curiosity research. Overall, there is evidence that games are a suitable space for studying curiosity, and vice-versa.

A study from 2015 specifically investigated curiosity-triggering events in a GBL application for learning mathematics [33]. In this study, the authors did not manage to show beneficial effects on performance in learning. This, they suggest, might have been due to certain decisions in their game's design, such as the involvement of a highly repetitive task. A challenge in designing a situation in which curiosity might occur, referred to by the authors as a cognitive conflict, is that it needs to invoke curiosity without confusing the player. Therefore, it can be said that designing for curiosity in an application for Game Based Learning requires careful balancing of several requirements, which need to be tested throughout the development. Additionally, existing work by To et al. [31] on how game elements can elicit curiosity can provide a more informed initial game concept. In their study, the authors follow a model of curiosity [17] that distinguishes between different triggers of curiosity. This approach is particularly useful for creating generalizable design guidelines, as it gives game designers a range of possible design interventions for invoking curiosity.

## 3 USER NEEDS ANALYSIS

While educational games are often developed to primarily benefit students, existing work in GBL has shown that there are in fact several stakeholders. In addition to students, there are teachers, parents, and developers to consider [1, 2]. Developers need to balance the needs of users with what can be created by the development staff. For CURIO the development staff is comparatively small, thus restricting the technical and aesthetic complexity when compared to high-budget games. Ideally, all stakeholders are taken into account and are able to influence the development process. However, prioritization is necessary when resources are limited. In the development of CURIO, we choose to prioritize the needs of teachers above those of other stakeholders. The reason for this is that it is ultimately the role of teachers to evaluate what supporting tools are viable in the classroom. Certainly there are several factors that teachers cannot influence. Nevertheless, at least within a typical Maltese classroom, teachers are unlikely to make use of teaching instruments that do not support their individual teaching style. As the development progresses, students and parents will be asked to provide feedback. Their perspective will therefore also shape the game, although to a lesser extend than that of teachers.

In order to get a better idea of what teachers expect from an educational game that is played within the classroom, we conducted three focus group sessions with 15 teachers in total.

### 3.1 Focus Group Sessions

The three focus groups conducted for our development efforts generally followed the same procedure, outlined in this section. Each group consisted of five teachers from STEM fields with ages ranging from 20 to 60. Five topics were used to guide the discussion over a duration of 1.5 hours: First, the teachers were asked to reflect on what they considered 'scientific curiosity' to be. This included both the definition of curiosity, as well as its purpose within education and life in general. Second, the groups discussed which subject matter readily invokes curiosity in their students. Teachers were also asked to contrast this with topics that are less likely to make students curious in their experience. Third, discussion concerning the use of digital tools in the classroom and in the context of formal education in general. Fourth, discussion about what aspects in a classroom game support their teaching efforts, as well as what details need to be kept in mind to not impact a teaching session negatively. Fifth, we asked teachers to discuss noteworthy examples of digital tools that not only support teaching efforts, but also make students curious to learn more.

Turning to the outcomes of the focus group, we found that usability was frequently mentioned as a crucial aspect for GBL efforts. Teachers emphasized that educational games for the classroom need to be mindful of the time and resources that they can provide. This was most apparent when the teachers were asked to discuss what CURIO should focus on. Apart of ease of use for teachers, it was also mentioned that students are often not the 'digital natives' that they are made out to be. Teachers further highlighted the need for flexibility when teaching, and the need to stay in control of the classroom at all times; a challenge especially when involving technology in the classroom. Another important aspect is an apparent relation to the teaching syllabus. Our interviewees noted that students would be happy to play games throughout the whole lesson, but need to pass a formal exam at the end. Other aspects that were mentioned surrounding this topic include the need for an appealing visual design, support of group work, independence from the Internet, ability to facilitate different interests, and an overview of past activities for review purposes. It should be noted that the teachers at times offered specific design ideas that we do not evaluate in detail. Examples are: suggestions to involve as many activities as possible, the addition of comics, or the use of 'bubbles with interesting facts'. Instead of understanding these suggestions as crucial features, we take them into consideration as elements that they believe students would like to engage with. When we asked the teachers for noteworthy examples, they mentioned *Kahoot!* [7] as a game that stands out in usability and in its ability to encourage participation. Generally, games that were mentioned were created specifically for educational purposes. The modification of existing games, such as *Minecraft* [24], was not brought up.

In the context of curiosity, we note that while the interviewees agreed on the importance of it to facilitate learning, they had difficulties in describing what it entails. Curiosity was frequently defined through curiosity itself, and participants could not agree on whether it requires some knowledge already or whether it can be invoked without. For educational purposes, curiosity was described as 'wanting to know', asking many questions, exploration, and experimentation. The teachers noted that it is important to let students come up with their own answers and also cautioned that formal education can 'kill curiosity with facts'. When asked to discuss suitable topics to invoke curiosity, the interviewees noted the presentation has a bigger impact than the topic itself. They highlighted that students require relatable real-life examples, but also the use of topics that are neither too difficult nor too easy.

## 3.2 Additional Requirements

So far, we have discussed the requirements that we consider central to the goals of the CURIO game. However, as is frequently the case in game development, there are additional design requirements that are part of the project. In addition to invoking curiosity in students, CURIO aims to support teachers specifically in areas of STEM; science, technology, engineering, and mathematics. CURIO is developed for use in Maltese schools which have identified a need to promote STEM areas. While Malta has taken action to improve student performance, the latest Program for International Student Assessment (PISA) has ranked Malta as one of the lowest scoring countries in the European Union [25]. As such, the design of CURIO needs to support education efforts specifically in STEM fields. Last but certainly not least, we want to emphasize that the enjoyment of players is an important requirement. Especially enjoyment on the side of teachers is easily forgotten, as they could be considered more facilitators rather than players themselves. However, the success of CURIO as a teaching tool arguably depends on how it is experienced by teachers.

# 4 CURIO: THE GAME

In this section we describe the design of CURIO and how insights from related work, a user needs analysis, and early focus groups helped to shape it. We begin with a general description of the game that has been designed in response to results of the user needs analysis. This is followed by a section on gameplay for teachers, and another that focuses on gameplay for students. At this point, we need to emphasize that the design of the game will likely change over the development period. This is because even well informed assumptions need to be play-tested; thus using feedback and gathered data to evaluate which parts of the design fulfill their intended purpose.

## 4.1 Game Description

CURIO is a real-time, multi-user classroom game in which students are tasked with answering exam questions through text input or images. If a question asks to name animals with more than four legs, the text 'Spider' is thus just as valid as an image showing a spider. The goal of the game is to decorate a virtual environment (literally featuring an exam paper), which is done by posing new questions about the answers that have been provided by the players. Going back to the example, decorations are thus created not by answering the exam question directly, but rather by posing new questions about the answers that have been given. As such, the focus of the game is on the development of new questions. At the same time, these questions can only be asked if answers have been proposed, thus requiring both the formulation of questions and answers to make progress.

Players in the game are guided and supervised by a special player character reserved for a teacher. Teachers supervise game sessions through a terminal that also serves as a shared overview for students in the classroom, e.g through a video projector. Outside of classroom sessions, students are able to customize their player avatars, while teachers can add or modify exam questions and additional content to support students.

The game aims to support teachers by providing them with a group environment that encourages students to conceptually explore a question beyond direct answers that can be given. CURIO aims to present itself as an educational instrument from beginning on, rather than over-emphasize its game elements. The rationale is that certain formal education elements, such as the use of exam papers and workbooks, are a reality for students in Malta. The involvement of game-based learning tools is not likely to change the format of an entire education system; at least not overnight. Positioning CURIO as an interactive preparation for an exam means

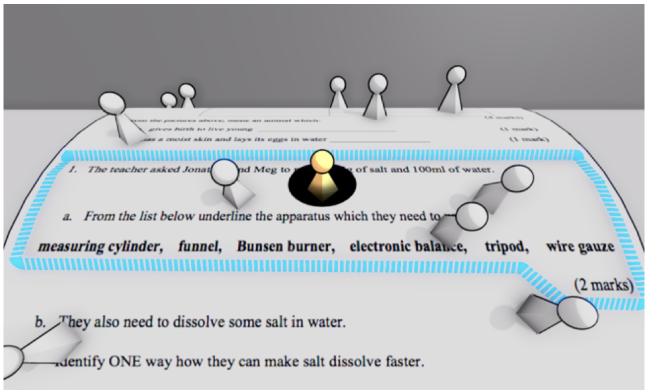


**Figure 1: Conceptual prototype screenshot of the game depicting the exam hub and a player 'entering' a question level.**

that game elements can surprise players. While this shift in presentation may be subtle, it is preferable over players expecting a game for entertainment purposes that then 'reveals' itself as a tool for learning, something that has been aptly referred to as "chocolate covered broccoli" [9]. This does not mean that entertainment is not a factor in CURIO. However, it is not the first priority, as is arguably the case for game-based learning applications in general. Apart of its role to support students, CURIO provides teachers with a tool to 'manage' group activities by giving them control over digital devices used in the classroom, and providing data that can inform their formal teaching efforts.

## 4.2 Gameplay

In CURIO, we consider both students and teachers to be players. The game is intended for a single teacher and 10-30 students. Student players and teacher players take on different roles in the game, but both access the same game environment and can see and interact with each other in it. Players assume control over a customizable virtual avatar that navigates a 3-dimensional environment from a 3rd person perspective. The game environment depicts an oversized exam paper, with players being able to walk on top of it (see Figure 1). Players can 'enter' exam questions with their virtual avatar. This will lead them into a separate 3D environment that represents the conceptual space of the question. In other words, each question can be thought of as a 'level', while the exam paper acts as a 'hub' that allows players to choose which level to access.

At the beginning, levels appear to be empty. Here, players can send out shock-waves to reveal hidden objects in the environment. These objects can be collected, upon which they turn into potential answers to the question that has led to the level. Every collected answer is added to a shared inventory that can be accessed by all players. Answers can also be added by players at any time, both as text or image (e.g. via the camera of a mobile device). To provide an answer to a question, players access the inventory and select an answer they want to 'plant' into the level. This creates a 3D object in the level that represents the given answer. Each planted answer in the level provides players with the ability to pose questions about that answer (see Figure 2). Questions may ask for clarification, but could also inquire about something that is only tangentially related to the original exam question. With each additional question, the planted answer grows in size within the level environment.

A small selection of hidden objects can also contain special machinations that are placed within the level upon their discovery. Players are able to interact with them to visualize functionality, such as illustrating how the opening of a funnel affects water flow and pressure. Such objects are developed for specific topics and are available at the discretion of the teacher.

When players return to the exam hub, they find that for each planted answer, a seedling has appeared on top of the exam question. These seedlings grow larger for each question that players have posed about a planted answer (see Figure 3). This means that most of the impact on the visual appearance of the exam hub comes from posing additional questions. While some exam questions might be simple enough to fully answer with a single answer, students are encouraged to come up with several answers that could contribute to the exam question, and thus create more opportunities for asking new questions. The focus is therefore not on getting to a perfect answer, but rather on encouraging students to think broadly about potentially relevant aspects. As such, teachers have to discuss with students why they think that an answer contributes to an exam question, as well as what follow-up questions are interesting to consider. In CURIO, this exchange is more important than whether the question is perfectly answered. At the same time, it also highlights that interactions in the game take place within both the virtual and the physical environment.

At the end of a game session, the exam paper hub should be overgrown with automatically generated vegetation and other visual elements. Since the extent of the coverage is directly connected to the amount of questions that players posed, this acts as a visualization of how active players have been for each exam question. At the same time, this is the goal that players are asked to accomplish, although it functions closer to a open-ended high-score than a binary winning condition. In summary, players in CURIO will go through the following sequence:

(1) Choose an exam question to work on and enter it.
(2) Reveal hidden answer objects or create your own.
(3) Plant an answer, thus creating the possibility for asking follow-up questions.
(4) Add new questions about planted answers.
(5) Repeat steps in a different exam question (steps can be interrupted and resumed freely).

Finally, every game session is ended by the teacher, which can be done at any time. Teachers are encouraged to discuss the answers that have been provided, as well as follow-up questions that students have posed. This can also be done throughout a game session instead of just at the end.

**Gameplay for Teachers:** While the gameplay in CURIO is focused on student players, the teacher takes on the role of a facilitating player that, ideally, also finds enjoyment in that task. In pen-and-paper roleplaying games, so-called 'Game Masters' guide the activities of participating players. Their role differs from that of other players, but they still engage in the game as players themselves as well. This is, essentially, the same role that a teacher should take in CURIO. Compared to student players, the teacher player has access to additional functionality and stands out by having a

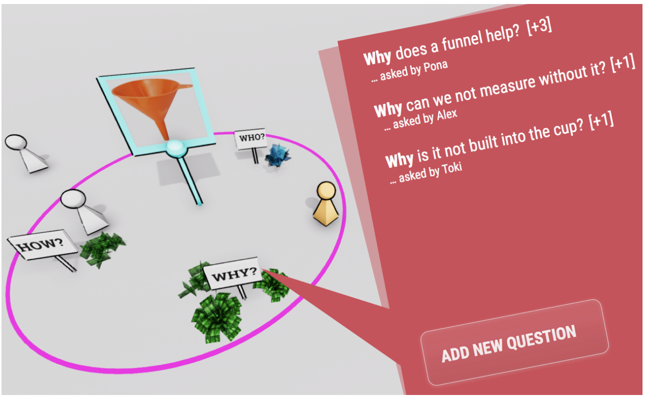


**Figure 2: Prototype screenshot showing a player in a question level next to a planted answer. The interface shows which follow-up questions have been added by players.**

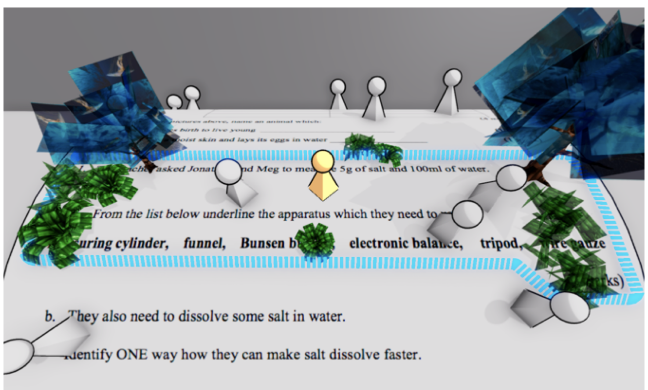


**Figure 3: Prototype screenshot of the exam hub after players have planted answers and added follow-up questions, leading to visual elements growing on top of the exam question.**

larger, faster moving avatar in the game. Additional functionality includes the ability to teleport between question levels, moderation of student players, and moderation of the game content. To moderate student players, the teacher can deactivate all screens, or just disable player movement for moments of discussion. They can also teleport all or some players to their own location within the game, which is useful when discussing specific answers or follow-up questions that have been added. Content moderation involves the ability to remove planted answers and follow-up questions by students in case they are deemed inappropriate.

Aside of gameplay that takes place in the classroom, teachers also prepare game sessions. This means to add an exam paper into the game, and then highlighting areas that belong to an exam question in order for students to interact with them. Teachers can then provide potential answers (which may or may not be correct) that will be distributed as hidden objects among the question levels.

## 5 DISCUSSION

At this point we will summarize the insights gathered in preparation for the CURIO project and discuss how they influence the design of the game. As a reminder, the game has two core requirements that it needs to fulfill: facilitate learning and invoke curiosity. Additionally it needs to support education in STEM fields, and provide an enjoyable experience to its players.

**GBL in the Classroom:** Both prior work and our own focus groups show that games in the classroom need to be designed for the role of teachers. In CURIO this is done in two ways: First, teachers are players themselves, put in charge of facilitating gameplay for students, but also able to participate. Second, teachers control the access to the game for all players and can use that control to create moments for discussion at any time. This is also the reason behind the open-ended gameplay in CURIO which does not feature a dedicated 'end state'. The game can be considered simple in terms of its design and technical features, as players have only few options for interaction. This simplicity is by design and should allow a better focus on formulating answers and follow-up questions within the game. It further means that players do not need to learn complex control schemes, which should ease concerns about difficulties with 'operating' the game. In terms of content, CURIO starts with an formal educational element that is cause for much anxiety in students: an exam paper. In 'decorating' an exam paper through conceptual exploration we believe that the game can be successful in alleviating some of the anxiety, and also show teachers that using CURIO can be part of preparatory lectures.

**Invoking Curiosity:** While curiosity can be satisfied, it often is part of invoking further curiosity about what has been learned [29]. In CURIO, this process is at the heart of its gameplay, as progress is primarily achieved by coming up with follow-up questions to answers that have been given. This also directly follows from our focus groups where teachers highlighted the importance of formulating new questions. Another aspect that was mentioned is experimentation and exploration. Both aspects are present in CURIO, although from a largely conceptual perspective, such as considering what follow-up questions can relate to a given answer. Following To et al.'s suggestions regarding designing for curiosity [31], we involve different methods of invoking curiosity. *Perceptual curiosity* is invoked by seeing other players' activity through the size of planted answers (and thus a wealth of connected follow-up questions) and having to interact with them to find out more. Another example is the search for hidden objects, and the chance that a hidden object turns into an interactive machination. *Manipulative* and *Adjustive-Reactive Curiosity* are triggered by the involvement of such machinations, as players are able to experiment with simulated physical processes. *Curiosity about the Complex and Ambiguous* is likely elicited by seeing other players' answers and follow-up questions. These might not always be clear and require further clarification, either by direct conversation or by posing follow-up questions within the virtual environment. *Conceptual Curiosity* is the most prominent method of invoking curiosity in CURIO, through what we suggest to be conceptual exploration in having players develop follow-up questions. The depth of such exploration then depends on whether teachers involve additional material, such as existing textbooks, to formulate answers. These are just some examples of a more intricate game design, but illustrate that even a relatively simple game provides many avenues for invoking curiosity.

**STEM and Player Enjoyment:** As previously mentioned, CURIO seeks to benefit specifically efforts to improve student performance in STEM fields. Aside of this, it also considers player enjoyment an important factor to ensure prolonged use. As STEM already consists of a range of fields, we argue that it is especially the methodology that provides a common ground that can be promoted in CURIO. At its core, all STEM fields require the development of questions that can be the basis for experimentation and analysis. Formal education often teaches knowledge that has been acquired without emphasizing the transient nature of such 'answers'. In promoting the importance of follow-up questions, CURIO aims to increase the performance of students in STEM fields not by teaching the underlying content, but by presenting an approach to gaining knowledge. At the same time, by using content from STEM fields and implementing interactable objects for experimentation, CURIO also offers more traditional ways to engage students with content from STEM.

Finally, while we do not expect CURIO to rival games that are developed for the sole purpose of providing entertainment, aspects such as player customization, a whimsical visual aesthetic, particle effects, and entertaining animations can play a role in increasing the enjoyment for its players.

## 6 CONCLUSION

In this paper, we presented our ongoing effort to develop CURIO, an educational game for Maltese classrooms that invokes players' curiosity as part of its gameplay. Prior research suggests that the role of the teacher needs to be considered to ensure successful use of such games. For this reason, we conducted focus groups with educators to better understand their needs. Their insights, as well as existing research in the field of game-based learning and designing for curiosity, are the basis for the design of CURIO. The resulting design promises to balance the different requirements with practical considerations, such as whether it can be achieved with a small development team. In focusing on formulating answers and new follow-up questions, CURIO is adaptable to different teaching styles and changes in content. On the other hand, it requires teachers to become active facilitators. This, together with concerns regarding ease of use, necessitates the development of instructional material for teachers next to the technical development of CURIO. The latter will also require ongoing user tests with teachers and students to evaluate how the design needs to be adjusted. Early feedback by teachers regarding the design of CURIO has already highlighted the potential challenge of leading to too many unfocused questions from students. Such concerns will require careful testing in a classroom environment. At this point, however, we believe that CURIO presents interesting opportunities for invoking curiosity in an educational game. This makes the project a valuable contribution to such efforts, and research into both curiosity and GBL in general.

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