Exploration through video games

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3 Creating a Game-Based Learning Toolkit for Fostering Curiosity

Chapter 2 outlined previous research on curiosity in and through games and the concept of game-based learning. The literature review showed how game-based learning efforts often focus on practicing learned material rather than stimulating curiosity. Additionally, literature looking specifically into how games elicit curiosity is limited. Thus, while games may seem like potential vehicles to elicit curiosity and exploration, e.g., in service of learning practices, it is not clear how that should be designed for and achieved.

The chapter examines how a game can be designed to elicit curiosity. It focuses on conceptual curiosity (Kreitler, Zigler, and Kreitler 1975a) when children are introduced to a new topic of study in school, with the externalization of that curiosity (i.e., exploration) being the formulation and discussion of questions.

> The research question that guides the work in this chapter is:
> **How can a game facilitate conceptual exploration?**

The study in this chapter describes the iterative development of *CURIO*, a game-based learning toolkit (also referred to as "gamekit" from here on) designed to support teachers in fostering conceptual curiosity in students. The project is funded by the *Erasmus+ Cooperation for Innovation and the Exchange of Good Practices* scheme with the goal of promoting interest in Science, Technology, Engineering, and Mathematics (STEM) subjects for children in primary education. As the project aims to stimulate interest in STEM (science, technology, engineering, and mathematics) topics in Malta, the game has to meet the needs of teachers and students in Maltese schools.

The study addresses the following research questions through a game artifact:

1. Can a classroom game around asking questions support teaching?
2. Does such a game elicit curiosity for topics presented as part of it?

The study's outcome is the development of the *CURIO* gamekit, informed by a user-needs analysis, an initial prototype development, and a re-designed game that is tested in a Dutch classroom. The game was developed by a core team consisting of a designer & programmer (the author of this thesis) and a designer & artist, with additional work outsourced to one freelance developer and one artist.

The chapter first describes the preliminary work in performing a user-needs analysis of the involved stakeholders through a series of focus groups (section 3.1). Based on the requirements resulting from this analysis, and additional requirements set out by the project design, a prototype (section 3.2) is designed that offers distinct gameplay to both students and teachers. The prototype is subsequently iterated to fit changing circumstances and needs of the stakeholders. This process results in the final version of the game, the *CURIO* gamekit (section 3.3). Before concluding the project development, the gamekit is evaluated with 25 Dutch elementary school students (section 3.4). Results of the evaluation study suggest that teachers and students see value in a classroom game emphasizing inquisitiveness as part of its gameplay. Students also appeared to show increased awareness of and interest in topics featured in the evaluation study, indicating that the game successfully elicited curiosity. The chapter concludes with a reflection on the gamekit, its potential use in classrooms, and its ability to elicit conceptual curiosity in children for a new topic of study (section 3.4.3).

Chapter Publications

Work presented in this chapter has been published in these peer-reviewed venues:

- **International Conference on the Foundations of Digital Games (FDG) – 2020**
  "CURIO 2.0: A Local Network Multiplayer Game Kit to Encourage Inquisitive Mindsets" (M. A. Gómez-Maureira et al. 2020)
- **International Conference on the Foundations of Digital Games (FDG) – 2018**
  "CURIO: A Game-Based Learning Toolkit for Fostering Curiosity" (M. Gómez-Maureira 2018)

3.1 User-Needs Analysis

The development of educational games often focuses on benefitting students. However, prior Game-Based Learning (GBL) work has shown the need to consider other stakeholders. In addition to students, teachers, parents, and developers are all part of developing a successful outcome (Berg Marklund 2015; Marklund, Backlund, and Engstrom 2014).

In the development of *CURIO*, the needs of teachers are prioritized above those of other stakeholders. This is because it is ultimately the role of teachers to evaluate what supporting tools are viable in the classroom. While there are several factors that teachers cannot influence, at least within a typical Maltese classroom, teachers will not use teaching instruments that do not support their teaching style. As the development progresses, students and parents are asked to provide feedback. Their perspective also shapes the game, although to a lesser extent than that of teachers.

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

3.1.1 Focus Group Sessions

The three focus groups conducted before the development of *CURIO* followed the procedure outlined in this section. Each group consisted of 5 teachers from STEM fields with ages ranging from 20 to 60. Five topics were used to guide the discussion over 1.5 hours:

1. Teachers were asked to reflect on what they considered to be the meaning of scientific curiosity. Their reflection included the definition of curiosity and its purpose within education.
2. The groups discussed which subject matter readily elicits curiosity in their students. Teachers were asked to contrast this with topics less likely to make students curious.
3. Teachers discussed using digital tools in the classroom and as part of formal education in general.

4. Teachers were asked to discuss what aspects of a classroom game support their teaching efforts and how to prevent such a game from impacting a teaching session negatively.
5. Teachers were asked to discuss noteworthy examples of digital tools that support teaching efforts and make students curious to learn more.

The outcome of the focus groups was that ease should be the most crucial aspect of GBL efforts. Teachers emphasized that educational games for the classroom need to be mindful of the time and resources they can provide. This notion was most apparent when teachers discussed the essential focus of *CURIO*. Besides ease of use, teachers mentioned that students are often not the "digital natives" they are assumed 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 a close relation to the teaching syllabus. Focus group participants noted that students would be happy to play games throughout the lesson but, on the other hand, must pass formal exams at some point. Other aspects that focus group participants mentioned include the need for an appealing visual design, support for group work, functional independence from the Internet, the ability to facilitate different interests, and an overview of past activities for review purposes. It should be noted that the teachers occasionally offered specific design ideas that were not further assessed in detail. Examples include 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, they are considered elements that teachers believe students would like to engage with.

When teachers were asked for noteworthy examples, they mentioned *Kahoot!* (Dellos 2015) as a game that stands out in usability and in its ability to encourage participation. Generally, games that were mentioned were explicitly created for educational purposes instead of entertainment games repurposed for learning purposes. The modification of existing games, such as *Minecraft* (Nebel, Schneider, and Rey 2016), was not brought up.

In the context of curiosity, interviewees agreed on its importance for facilitating learning but had difficulties describing what it entails. Curiosity was defined with related attributes, and participants could not agree on whether it requires some existing knowledge or whether it can be elicited without any prior interest or knowledge. For educational purposes, curiosity was described as "wanting to know", asking many questions, exploring, and experimenting. Teachers noted the importance of letting students come up with their answers and cautioned that formal education could "kill curiosity with facts". When asked to discuss suitable topics to elicit curiosity in STEM, the interviewees noted that the presentation had a more significant 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.

3.1.2 Additional Requirements

In addition to eliciting curiosity in students, *CURIO* has to support teachers specifically in areas of STEM. *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 *Program for International Student Assessment* has ranked Malta as one of the lowest-scoring countries in the European Union (OECD 2016). As a result, the design of *CURIO* needs to support education efforts in one specific subject and across different STEM fields.

The technological limitations within the classroom set out further requirements. The *CURIO* project is based on the *One Tablet Per Child* initiative to provide every child in Maltese primary schools with a tablet device for learning purposes. Thus, the game should ideally be developed to run on these tablets and within the school infrastructure. Usability for teachers and students using this technology is essential.

Finally, developers need to balance the needs of users with what can be created by the available development staff. The *CURIO* development team is small (i.e., two developers), thus restricting the technical and aesthetic complexity compared to high-budget games. Ideally, all stakeholders are considered and can influence the development process. However, prioritization is necessary when resources are limited.

3.2 Initial Prototype

This section describes the initial prototype design of *CURIO* and how insights from related work and focus groups helped to shape it. It should be noted that, as is often the case in the iterative development of projects, the design of the game changed over time. In the case of *CURIO*, the game underwent a significant change after initial development conclusions, as the initial plan was deemed too ambitious to be fully realized (see section 3.2.5). This assessment led to the development of a new design described later in section 3.3.

3.2.1 Prototype Design

For the prototype, *CURIO* is designed as a real-time, multi-user classroom game in which students are tasked with answering exam questions through text input or by providing images. If a question asks to name animals with more than four legs, the text input "spider" would be just as valid as an image showing a spider.

The game's goal is to decorate a virtual game environment set upon the backdrop of an exam paper (seen in figure 3.1), which is done by posing new questions about the answers that other players have already provided. Decorations are thus created not by answering the exam question directly but instead by posing new questions about the answers that have been given. As such, the game's focus is on developing 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 in decorating the environment.

Players in the game are guided and supervised by a unique player character that is reserved for the teacher. Teachers supervise game sessions through a game terminal that also serves as a shared overview for students in the classroom, e.g., through a video projector. Outside classroom sessions, students can 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 a group environment that encourages students to conceptually explore a question beyond the direct answers that can be given. *CURIO* aims to present itself as an educational instrument from the start rather than over-emphasize its game elements. The rationale is that certain formal education elements, such as 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 that game elements can surprise players. While this shift in the 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" (Granic, Lobel, and Engels 2014).

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 GBL applications in general. Besides 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.

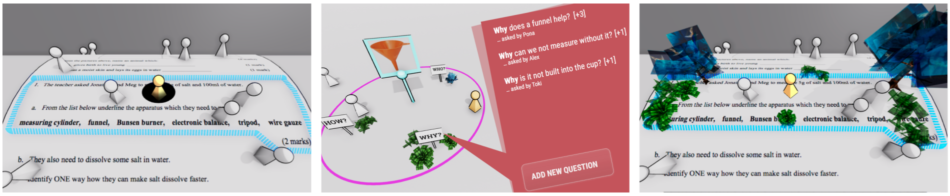

Figure 3.1: Three screenshots of the initial prototype. The first shows the exam hub and a player entering a question. The second shows the player in an entered question level next to a "planted" answer. The interface shows which follow-up questions have been added by other players. The last image shows the exam hub again, and the decorations that are created as part of adding follow-up questions.

3.2.2 Design Considerations

The insights gathered in preparation for the *CURIO* project have led to three considerations that guided the game's design.

GBL in the Classroom: Both prior work and the focus groups show that games in the classroom need to be designed for the role of teachers. In *CURIO*, this should be done in two ways. First, teachers are players, put in charge of facilitating gameplay for students and acting as participants themselves. Second, teachers control the access to the game for all players and can use that control to create moments for discussion at any time. For this reason, the initial prototype of *CURIO* does not feature a dedicated end state and is, instead, a playful activity that can be suspended at any moment. The game can be considered simple in terms of its interactive features, as players have only a 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 a formal educational element that is the cause of much anxiety in students: an exam paper. In decorating an exam paper through conceptual exploration, the game may alleviate some of the anxiety and signal to teachers that using *CURIO* can be part of preparatory lectures.

Eliciting Curiosity: While curiosity can be satisfied, it is often part of eliciting further curiosity about what has been learned (Schmitt and Lahroodi 2008). In *CURIO*, this process is at the heart of its gameplay, as progress is achieved by coming up with follow-up questions to answers given. This also follows from 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 (To et al. 2016), different methods of eliciting curiosity are considered. "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 meant to be elicited by the involvement of such machinations, as players can experiment with simulated physical processes. "Curiosity about the Complex and Ambiguous" is meant to be elicited by seeing other players' answers and follow-up questions. These might not always be clear and require further clarification, either by a direct conversation in the classroom, or by posing follow-up questions within the virtual environment. "Conceptual Curiosity" is the most prominent method of eliciting curiosity in *CURIO* through having players formulate follow-up questions. The depth of such exploration then depends on whether teachers involve additional material, such as existing textbooks, to formulate answers.

STEM and Player Enjoyment: As previously mentioned, *CURIO* seeks to benefit efforts to improve student performance in STEM fields. Besides this, player enjoyment is another essential factor in ensuring prolonged use. As STEM already consists of a range of fields, it is primarily the methodology that provides a common ground that is promoted in *CURIO*. At its core, all STEM fields require formulating questions that can be the basis for experimentation and further analysis. Formal education often teaches knowledge that has been acquired without emphasizing the transient nature of such answers. In focusing on the importance of follow-up questions, *CURIO* aims to increase students' performance 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 interactive objects for experimentation, *CURIO* also aims to offer more traditional ways to engage students with content from STEM. It is important to note that player enjoyment in the game is not meant to rival games that are developed for the sole purpose of providing entertainment. Instead, game elements such as player customization, a friendly visual aesthetic, and "juicy" feedback elements (Juul 2010) increase the enjoyment of activities that can be carried out in the game.

3.2.3 Gameplay for Students

In *CURIO*, both students and teachers are considered players. The game is intended for a single teacher and 10-30 students. Student players and a teacher take on different roles in the game, but both access the same game environment and can see and interact with each other within it. Players assume control over a customizable virtual avatar that navigates a 3-dimensional environment from a third person perspective. The game environment depicts an oversized exam paper, with players being able to walk on top of it (see the first image in figure 3.1). Players can access exam questions with their virtual avatars. This leads them into a separate 3D environment that represents the conceptual space of the question. In other words, each question can be considered a game level, while the exam paper acts as a hub environment that allows players to choose which level to access.

In the beginning, levels appear to be empty. Here, players can send out shockwaves to reveal hidden objects in the environment. These objects can be collected, which turns them into potential answers to the question that has led to the level. Every collected answer is added to a shared inventory that all players can access. Players can also add answers at any time, both as text or image (e.g., via a mobile device's camera). 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 allows players to pose questions about that answer (see the second image in figure 3.1). 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 unique machinations that are placed within the level upon their discovery. Players can 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 teacher's discretion.

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 players have posed about a planted answer (see the last image in figure 3.1). 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 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 an answer contributes to an exam question and 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 number of questions that players posed, this visualizes 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 an open-ended high score than a binary winning condition. In summary, players in *CURIO* will go through the following sequence:

1. Choosing an exam question to work on and "enter"
2. Revealing hidden answer objects or creating new ones
3. Planting an answer, thus creating the possibility for asking follow-up questions
4. Adding new questions about planted answers
5. Repeating steps in a different exam question

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

3.2.4 Gameplay for Teachers

In *CURIO*, 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 also engage in the game as players themselves. 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 more prominent, faster-moving avatar in the game. Additional functionality includes teleporting between question levels, moderation of student players, and moderation of the game content. To moderate student players, the teacher can deactivate all student screens or disable player movement for moments of discussion. They can also teleport all or some players to their 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 from the gameplay that takes place in the classroom, teachers are asked to prepare game sessions in advance. This means adding an exam paper into the game and highlighting areas that belong to an exam question 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.

3.2.5 Prototype Conclusions

The initial prototype of *CURIO* was designed to combine insights from prior work on curiosity-driven exploration, teachers' needs, and the development grant's requirements in a way that is both educational and entertaining for students. It sought to directly include existing teaching material in the form of exam papers and reframe the context away from assessment to perceiving a potential for conceptual exploration.

However, one type of stakeholder that was not taken sufficiently into consideration for the prototype was that of the (two-people) development team. Towards the end of the development of the initial prototype, it became clear that the amount of development work would not be sustainable to realize the proposed game design.

While development efforts typically undergo multiple iterative changes, these changes tend to become smaller in scope as the development progresses. This progression happens because substantive modifications at a later point become more costly in terms of development work. In the case of *CURIO*, the first quarter of the overall development time focused on creating a comprehensive game design based on what the development team believed could be achieved technologically and organizationally.

However, as time progressed, important development details kept changing. Eventually, *CURIO* is intended for use in Malta, where the public views game-based learning skeptically. For example, a suggestion received at the first public presentation of the project was to forego mention of the word "game". In Malta, games are closely related to gambling, based in part on the prolific local gambling economy. As such, educational and game design considerations also had to contend with political realities that made the development progress more challenging, requiring more time to organize playtesting and focus groups on the topic.

At the same time, technological infrastructure in the classroom turned out to be limited and varied between schools. In the end, this meant to develop *CURIO* in a manner that would allow for a broader range of target platforms and with ranging connectivity options while retaining the core of the game: to let students conceptually explore topics and do so in a shared virtual environment with their teacher. To retain the spirit of the game, the existing design and planned aesthetic had to change to complete development in the remaining time. Especially given that students and teachers need to feel confident in the consistent functionality of a game-based learning kit, the redesign removed some of the costlier design choices of the original game in order to provide that consistency.

Although a significant change in design is not necessarily standard in iterative development, it is also not unique to *CURIO* or game development in general. The funding realities of research projects can make it challenging to implement significant design changes, as a project is typically approved based on a proposed research design. However, in developing an applied game, work on the prototype can be instructive on whether a proposed design can be realized on the level of quality necessary to make it successful. In this case, it revealed that the initial design could not be realized without compromising on the implementation quality.

Public funding is typically granted based on a plan outlining how the partners will spend the received resources. Reworking a large part of a project can seem to run counter to this agreement. However, it can be argued that it is in the public interest to ensure that developers use funding in a manner consistent with the spirit in which it was granted. Doing so should be preferable over carrying out a plan regardless of what discoveries might occur during the project. In the case of game development (and possibly development efforts in general), making necessary changes might be prudent as long as it is possible to implement them with the remaining resources.

It is further essential to report such changes in academic literature. The development of serious games may otherwise appear to result from a series of iterative improvements in which no development work is ever lost. This is likely not the case, as the development of entertainment games frequently leads to work being discarded in light of new knowledge.

Even the redesign of *CURIO* presented in the subsequent sections is not guaranteed to succeed in providing teachers with a valuable teaching platform. Multiple evaluation studies, such as the one described in section 3.4, are required to assess whether *CURIO* can be considered a valuable tool for teachers. At the same time, maintaining the initial design would have required a different target environment or additional resources, neither of which would happen.

3.3 The *CURIO* Gamekit

This section describes the design of the *CURIO* “gamekit”, a label chosen to indicate its use as a game-based teaching toolkit. The design is based on insights from the GBL field, designing for curiosity, results of focus groups with teachers, and development considerations of an initial prototype.

Figure 3.2: Screenshot of the *CURIO* gamekit website, showing one of the characters that players can encounter in the game.

In the *CURIO* gamekit, students work in groups to restore lost curiosity to a fictional galaxy besieged by the *Haze of Confusion*, the game’s antagonist. The *Haze* sweeps across the galaxy, draining the planets’ inhabitants of their enthusiasm for a particular topic. Students play individually but are sorted into three teams (blue, red, and yellow). By visiting the planets and asking the inhabitants questions, the students are tasked with helping them to regain interest in their topic. Eventually, students face the *Haze* and answer multiple-choice questions to defeat it. Once the students save the galaxy from the *Haze*, they can spend points earned during play to decorate their spaceship.

Game scenarios are prepared in advance by teachers for each game session. Scenarios determine the topics of the individual planets (conceptually functioning as subtopics grouped under a broader main topic) and the questions posed by the *Haze* in the final confrontation. For teachers, *CURIO* serves as a tool to engage students in a new topic, assess existing knowledge, and receive input for upcoming classes. While playing, the teacher acts as a game master who controls the game's flow.

3.3.1 Game Flow

Each game session consists of four parts: the beginning of the game, multiple game rounds, up to three endgame rounds, and a post-game sequence.

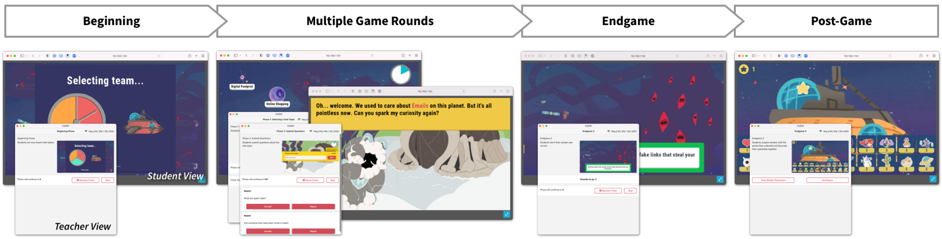

Figure 3.3: Diagram showing the four major parts of a game session. For each part, an example screenshot of the student and teacher view is shown.

The beginning of the game contains a short introduction that presents the topic of the game session and assigns players to one of three teams. The game session then goes through multiple game rounds in which players move from planet to planet to re-energize themselves by formulating questions about the topic. Game rounds consist of the following phases:

1. Setting a course by voting on which location to visit next
2. Landing on a planet based on the vote result
3. Generating curiosity energy by asking questions
4. Reviewing questions that were asked
5. Resolving the location visit

In the first phase, teams choose which planet to move to on a galaxy map of interconnected planets. In phase 2, teams land on a planet and are presented with a sub-topic. In phase 3, individual players formulate new questions about a sub-topic. In phase 4, teams see how many questions they created and which of those were considered noteworthy by the teacher. In phase 5, the performance of each team is evaluated, and questions are discussed in the classroom.

Each game round allows teams to move closer to an indicated target destination: the location of the *Haze of Confusion*. The duration of a game session depends on how long it takes the first team to reach the *Haze*, which then triggers the endgame for all teams regardless of their location on the map. Teachers can trigger this conclusion in the first phase of each game round to control the length of a game session.

The endgame is a confrontation between the *Haze* and the student teams at the end of a game session. At this point, players need to correctly answer questions about the session topic to combat the *Haze*. Each correctly answered question lets teams use their energy — acquired through creating questions throughout the game session — to disperse the *Haze*. The endgame itself consists of smaller endgame rounds in which the teams receive a question that needs to be answered, which is then resolved to show which teams answered correctly. By default, the endgame lasts for three rounds in which at least one team answers correctly. Teachers can change this setting both in the game setup and during the endgame.

All game rounds are synchronized among all players, meaning that individual players cannot proceed to the next round until all players are done. In practice, every game round takes place on a global timer or requires the teacher's confirmation. Timers can be modified by the teacher in the game setup and can be paused and resumed to facilitate discussion in the classroom at all times.

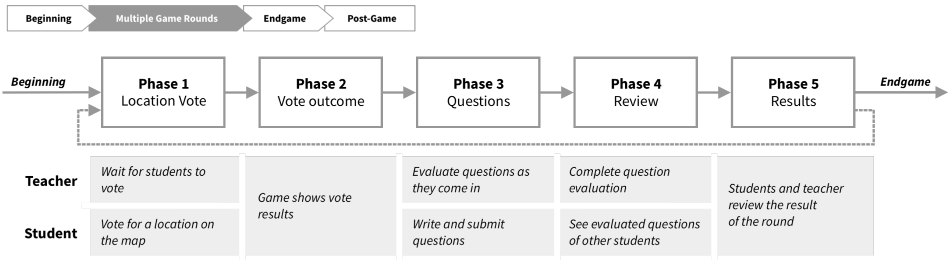

Figure 3.4: Flowchart of the five phases of a game round.

3.3.2 Student Side

This section describes students' actions in each of the four parts of a game session. The game starts with an animation that shows the *Haze of Confusion* spreading across a fictional galaxy. The sequence introduces students to the threat they need to defeat and then shows them which team they are part of. The introduction is followed by multiple game rounds, each broken down into individual phases.

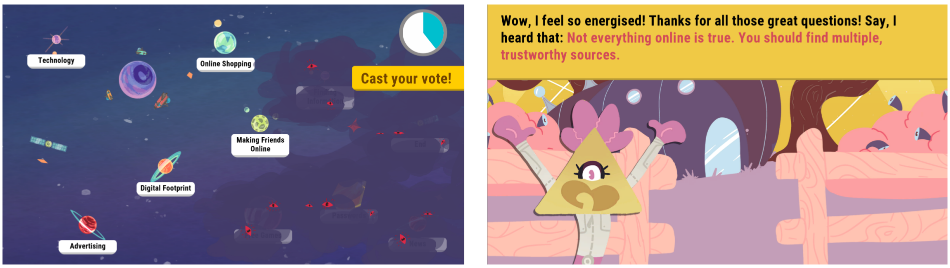

Figure 3.5: Screenshots of the student side of the game. Left: Main game screen, showing the map where students can vote for their next destination (i.e., sub-topic). Right: A planet's resident is shown to be re-energized by students' questions and shares some information about the current sub-topic.

Phase 1: Vote for target location

Students see the map of the galaxy, which shows the three player ships and several planets with sub-topics connected to them. The exact layout of the map is randomized upon starting the session. In this phase, students individually vote for which planet they want to visit. Most of the map will be covered by a "fog of war" at the start of the game, limiting the students' options. The neighboring planets will be unlocked as they visit planets and become available for selection. In the first round, player ships will appear on the far left side of the map around a space station. In subsequent game rounds, they appear from the last selected planet, revealing any neighboring planets.

Phase 2: Outcome of the vote
An indicator flashes across the available planets, building anticipation before the result of the vote is revealed. The planet that was chosen by the majority of students becomes highlighted. In case of a tie, the planet is chosen randomly from the top choices. The three player ships teleport away from their current location and appear at the new location, where they land on the planet.

Phase 3: Ask questions
The game transitions from the map view to a view of the planet. Each planet has a different aesthetic and inhabitant, with seven unique options. The planet appears desaturated in color, and the *Haze* surrounds the inhabitant. The inhabitant welcomes the player in a lethargic manner. They suggest that the players ask them questions about the planet's sub-topic to spark their curiosity again. Students are then provided with an interface through which they can type in questions to ask as many interesting questions relating to the sub-topic as possible within the time limit.

Phase 4: Question review
While the teacher evaluates the incoming questions, students are shown questions posed by the class that the teacher has already accepted. Each question also shows the author for other students to see.

Phase 5: Round results
Students see the planet view and the inhabitant again. With their curiosity restored, the inhabitant is no longer affected by the *Haze* and the planet itself has been revitalized. The inhabitant thanks the students and shares some information based on the sub-topic. Depending on the cumulative number of accepted questions from a particular team, the inhabitant is shown to be very happy or somewhat neutral. The information the students receive is the same regardless.

The game continues in rounds following these phases until the endgame is triggered. This can happen in two ways. First, the students may vote to end the game in phase 1.

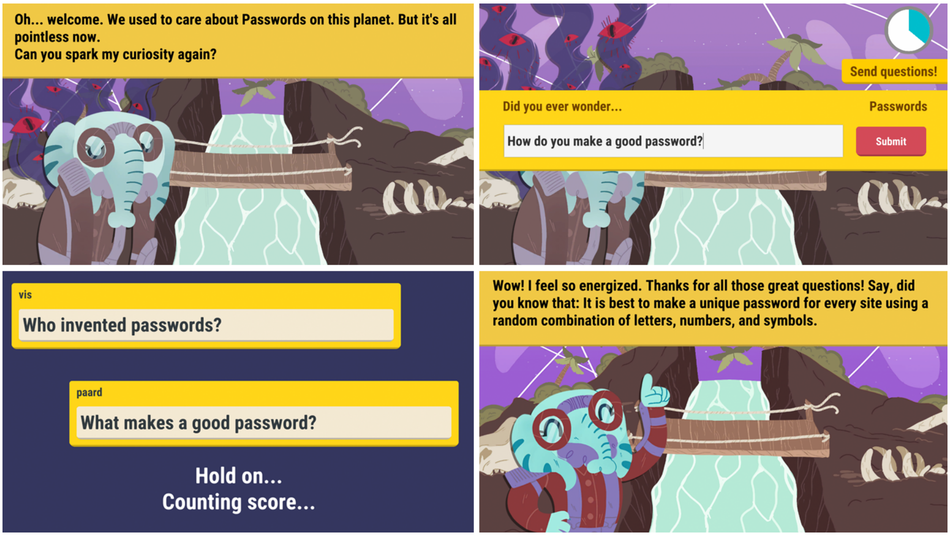

Figure 3.6: Screenshots showing the game phases for students after landing on a planet.

This requires them to uncover enough of the map to reveal the endgame node, visualized by another space station. Second, the teacher may trigger the endgame in phase 1, regardless of whether the endgame node was voted on or was even available to students. The endgame is split into the following phases.

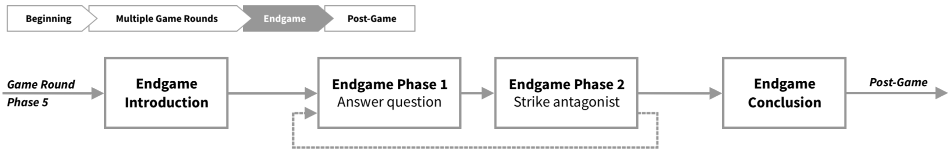

Figure 3.7: Flowchart of the endgame phases.

Endgame Introduction

The player ships travel to the final node on the map, and the game pans towards the right to reveal the *Haze*. From here, the final confrontation begins.

Endgame Phase 1: Answer question

The students are posed a question by the *Haze*. The question will relate to one of the sub-topics they visited, and the correct answer is the bit of information they learned from the inhabitant they helped. This aspect of *CURIO* aims to check whether students paid attention during the sessions and absorbed the information.

Endgame Phase 2: Strike antagonist

Depending on how the students answered the multiple-choice question, each team shoots a rocket at the *Haze*. If a majority of the students in a team answered correctly, the rocket is visually larger. The game repeats endgame phases 1 and 2 until the students answer three questions. If less than three sub-topics were visited, the phases would only repeat for that amount. Once the students answer enough questions, the game moves on to the endgame conclusion.

Endgame Conclusion

An animation shows the player ships defeating the *Haze* successfully, bringing the game to a satisfying conclusion.

Post-Game Activity: Decorate ship

Students earn points throughout the game session by asking questions and answering the multiple-choice questions correctly in the endgame. Students use the points in this last activity of the game. A large version of the team spaceship appears on the screen, which students can decorate with virtual stickers using their points. All students decorate the ship together, meaning they will see each other's stickers as they place them. This concludes the game session with a small reward for the students. The final picture of the ship can be saved as a screen capture as a memento of the game session.

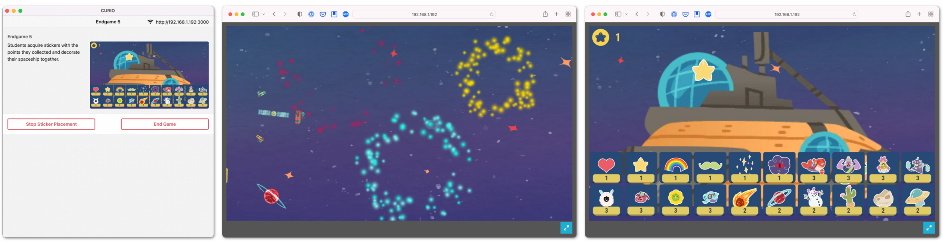

Figure 3.8: End of the game for students: decorating the ship with stickers

3.3.3 Teacher Side

While students play the game, teachers act as the “game master”. The teacher’s involvement starts with preparing the scenario for a game session. The teacher can open their side of the *CURIO* application to manage classroom and scenario files.

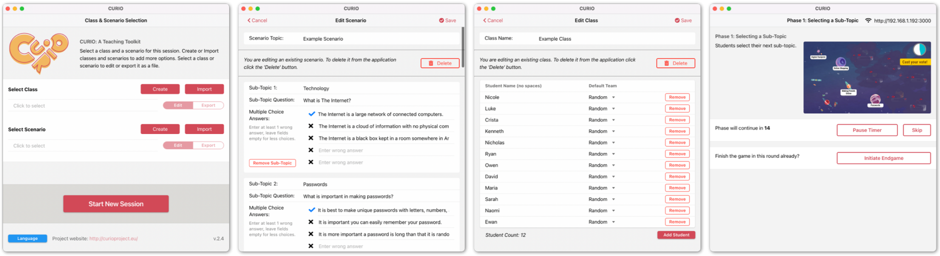

Figure 3.9: Screenshots showing the teacher interface.

Classroom file

The classroom file holds the login name of all students in a class. Students log in using their name at the game session’s start. The teacher can, therefore, know who asked particular questions or how individual students answered the multiple-choice questions in the endgame.

Scenario file

Scenario files hold the information for a particular scenario. The teacher sets an overarching topic for a game scenario (e.g., “The Internet”, “Physics”, “Algebra”). They then define sub-topics (e.g., “Online shopping”, “Passwords”, “Digital footprint”) with a minimum of one sub-topic. The teacher provides an exam question for each sub-topic and the answer to that question. The students can encounter these questions in their final confrontation with the *Haze*. They can also discover the correct answer to the question if they visit the planet corresponding to the sub-topic during the session. Because of how the planet inhabitant conveys the information, it is ideal if the answer forms a standalone sentence. The teacher also provides between one and four wrong answers to the question that appear as part of the multiple-choice interface.

The teacher selects a created classroom and scenario file from the main menu. With both selected, they can start a game session. Teachers then see a list of the names in the classroom file. From this point on, students can connect to the teacher's IP address using their own devices and log in to the game using a name in the classroom file. The teacher sees a student's status change in the list when they log in and their team (red, blue, or yellow). Team sorting is random initially, with students being distributed across the three teams equally as they log in. The teacher can overwrite the sorting manually to establish groups.

Once all students have logged in, the teacher starts the game. From this point on, the teacher application follows the same phases as the student application. Some phases are timer-based and will advance automatically, while others will only do so when the teacher initiates the next phase. The interface shows the phase the game is in, as well as a short description of that phase. A screenshot from one of the running student applications is periodically sent to the teacher application (every 5 seconds) to inform the teacher of what students see at that moment on their screens. The following sections describe the phases that require specific input from the teacher. Any other phases are timer-based by default and will advance without interaction. Any phase can be advanced before the timer runs out or can be paused by the teacher.

Phase 1: Vote for target location
There is no specific interaction required from the teacher, but they can decide to initiate the endgame early in this phase. The application will ask for confirmation before triggering the endgame. Selecting this option will override the vote of the students for this round. Instead, the ships advance to the confrontation with the *Haze* in phase 2.

Phase 3 and 4: Evaluate questions
Questions asked by the students will appear in the teacher application. The teacher can choose to accept or reject a question. Each student and their team will earn a point for each accepted question. The questions appear in batches. Once the teacher processes all available questions, questions submitted in the meantime appear next. This process repeats until no more questions are left to assess. Phase 3 will advance automatically for the students after a set timer, while phase 4 will remain active until the teacher has assessed all the questions and decides to move on to the next phase. Phase 4 is the most suitable moment to pause the game session for a longer time and discuss some of the questions submitted in that round.

The phases repeat until the students or the teacher triggers the endgame. The game requires no additional input from the teacher once the endgame begins but can be paused by them at any point. Students answer the multiple-choice questions and defeat the *Haze*, after which they decorate their ship. The teacher can decide when to end the game session for everyone by closing the teacher application. This automatically also closes the game for all students.

CURIO saves the submitted (and accepted) questions for each session, including which student asked each question. This information is available to teachers and can help plan upcoming lessons or have further discussions and activities in class about the topic that the game session covered.

3.3.4 Technology

While the design of the *CURIO* gamekit consists of two components (teacher and student side), the application runs as a single executable on the computer of the teacher (supporting Windows, Mac, and Linux). The executable, created using the *Electron* software framework (OpenJS Foundation 2019), opens the teacher interface and starts a local server in the background. The server hosts a WebGL application, created using the *Unity* game engine (Unity Technologies 2018) that students access by connecting to the server's IP address (prominently displayed in the teacher interface) via any internet browser capable of displaying WebGL content. Teachers can also change their computer network name so that the server is reachable by using a more memorable address, such as ***http://curiogame.local*** or similar.

Students can use laptops, desktop computers, or mobile devices to load the WebGL application, thus allowing for a variety of different devices and operating systems. Since the teacher hosts the WebGL application on their computer, student devices need to connect to the same local network as the teacher's computer. None of the machines require access to the Internet — once students access the WebGL application, their browser connects to the teacher interface via the local server for any communication about game states. As long as the teacher keeps their interface open, the game is accessible to students. By closing the teacher interface, the server is shut down as well, thus making the student side of the application unavailable. The student side detects this and informs students that the game has been closed.

The student side application can also run as a native *Android* or *iOS* application, which requires installation on each device. In this case, students do not use a browser. Instead, they use the native application to connect to the server on the teacher's computer. Students enter the IP address or computer name address of the teacher's computer into the native application to connect to the server. Otherwise, the game functions the same as the browser version.

All data in *CURIO* is created on the teacher's computer and accessed from there. The teacher application stores all scenarios and gameplay data in a local database in the application folder. Teachers can export created scenarios and class lists for backup purposes or to share them with colleagues. Any identification of individual students is limited to the name that teachers give them within a class list. They can use the first name of a student or a nickname that students choose for themselves.

3.4 Evaluation Study

The involvement of the development team (and the author of this thesis) in the *CURIO* project was set to end before the game would be made available to Maltese schools. Toward the end of the project timeframe, an evaluation study was conducted with 25 students at a Dutch primary school. In this study, students used a functional version of the *CURIO* gamekit. At the point of testing, the game did not yet include all final game assets (i.e., some game graphics were still a work in progress). The previously described end-game and post-game activity had also not yet been implemented. However, the game was sufficiently completed to test its core mechanic (i.e., asking and discussing questions) in a classroom setting.

The study's goal was to gather feedback from the teacher and students after playing the game. Measures included observational notes, a lightly structured (group) interview of the students, an interview with the class teacher, and a child-friendly game experience questionnaire; the Extended Short Feedback Questionnaire (eSFQ) from Moser et al. (2012).

Figure 3.10: Overview of the evaluation study environment.

3.4.1 Procedure

The experimenters met with the teacher to discuss the testing procedure before the session. The experimenters then tested the reliability of the wireless network and went through all steps of *CURIO* to ensure its functionality.

The teacher introduced the experimenters to the class. In addition to providing a supporting role, they could monitor the students' devices from their computers during the session. One of the experimenters fulfilled the role of the teacher during the test session, while the second took observational notes. The teaching experimenter explained the test's purpose and mentioned to students that their feedback could improve the game for others who would use the application in the future.

The teacher formed groups of students instead of each student participating with an individual device. Instead of using 25 devices, groups of 4-5 students shared a total of 6 *Chromebooks*. Rather than identifying each player by name, teams could choose animal names: fox, rabbit, frog, snake, fish, and hedgehog. A group was thus referred to as, for example, player "fox". Due to a technical issue, these six groups were distributed unevenly over the three in-game teams, leading to unequal distributions in team sizes.

After the experimenter ensured that students had no remaining questions about the test procedure, they presented the topic of the game session: The Internet. The experimenters chose this topic in advance with the teacher, which students were likely familiar with, but had not discussed in depth. Students played three rounds in which they chose sub-topics related to the session topic. The topics chosen by popular vote within the game kit were: "technology", "making friends online", and "online shopping".

A short discussion followed each game round, during which the experimenter highlighted some questions students had provided. The questions formed a starting point to assess what students already knew about the sub-topic and trigger further consideration. The experimenter paired such inquiries with new information that students might not yet be aware of. In each case, the discussion was kept short as the allotted time before the end of class was limited. In a normal teaching situation, teachers would likely be able to schedule their time differently and continue for longer, depending on what inquiries are formed by the students.

After the game session concluded, the experimenter asked students for their opinion on the game, focusing on feedback that could improve it. This exchange was followed by handing out anonymous single-sheet questionnaire forms — the eSFQ mentioned in section 3.4 — to gather individual feedback. The teacher took over once students completed the forms, discussed some school-related matters, and ended class. The experimenters then discussed the test session with the teacher and took notes of what the teacher thought about the gamekit and its functionality.

3.4.2 Results and Interpretation

The active part of the user test session (that is, playing the game, excluding prior explanations) lasted roughly 30 minutes. All participating students filled in the eSFQ (***n=25***). Students ranged from ages ***8-10*** (***Mn=9.4***, ***SD=0.6***). The gender distribution was ***16*** female students (***64%***) and ***9*** male students (***36%***).

Enjoyment (measured in the eSFQ by filling in a thermometer depicting increasingly happy emojis and scaled 1-5) was on average rated ***3.9*** (***SD=0.9***). When asked whether they would want to play the game again, ***18*** marked “Yes” (***72%***), ***5*** marked “Maybe” (***20%***), and ***2*** marked “No” (***8%***).

The three Likert-scale questions yielded the following results (rated from 1 to 5, with 5 indicating the highest agreement):

- “I wanted to continue playing to see more of the game” — ***Mn=3.9***, ***SD=1.1***
- “I was curious about what would happen in the game” — ***Mn=3.9***, ***SD=1.2***
- “I was looking for explanations for what I encountered in the game” — ***Mn=3.0***, ***SD=1.4***.

Ratings of the first two statements suggest that students were engaged and focused on the task. The third statement received mixed ratings. It is reasonable to assume that this is because the game does not present events that students can investigate further. Instead, students need to consider what could make a virtual character interested in a topic. It can be hypothesized that the overall narrative of the game (a *Haze of Confusion* affecting a galaxy) is only a mild trigger for investigating a given sub-topic. However, given that the narrative is primarily a framing device for the involved sub-topics, it is an acceptable shortcoming as long as the gamekit serves as a platform for shaping discussions within the classroom. In addition, the question being somewhat complex itself possibly contributed to the mixed results.

In terms of labels that were marked by students in the eSFQ, the three most frequently were: “Fun” (***80%***), “Easy” (***60%***), and “Great” (***40%***), while the three least used labels were “Boring” (***20%***), “Difficult” (***20%***), and “Childish” (***0%***).

When asked to mark labels regarding how it was to play the game with others, the three most picked labels were “Fun” (***80%***), “Satisfying” (***64%***), and “Cooperative” (***60%***), while the three least used labels were “Competitive” (***8%***), “Discouraging” (***4%***), and “Angry” (***0%***).

Based on observations from the test session, students were engaged in the game and invested in performing well. Students appeared to understand that performance was connected to asking many questions and the quality of such questions. This understanding was evident through the team discussions that emerged in the class and was also commented on by the teacher. It became evident that “something happening on-screen” was an important reminder for students to remain focused on the task. Students became noticeably louder during phases in which the game kit informed them to wait for the teacher to catch up on evaluating questions. Given that the teacher is occupied during this time, the game kit should provide support in the form of offering helpful information to students.

In the group discussion, students noted various reasons for enjoying the game. They enjoyed coming up with questions and cared about whether their questions would be discussed in class. The chosen topic was one that all students knew of but had never given much thought about. One student commented that asking questions made them think more deeply about the topic than they usually would. The student further noted that it made them realize that they knew more about it than they had initially thought. While students generally enjoyed working in teams, at least one younger student felt overshadowed by teammates claiming control of the device. Due to the technical mishap in uneven team distribution, some students perceived the competitive aspect as unfair. Overall, students did not mention competition as particularly positive, and it sooner had the potential of creating a hostile situation for the losing students.

The final discussion with the homeroom teacher highlighted the potential for the application, especially in modern teaching environments involving (mobile) computers. The teacher mentioned they would use a tool like *CURIO* in their teaching. In this particular school, the teaching method is shifting towards a project-based approach, in which groups of students formulate a research question and examine it for some weeks. The teacher noted that *CURIO* would be a good fit at the start of such a project to help students come up with questions to explore. They also preferred having students control the game individually rather than in teams so that each student could think of questions at their own pace. The teacher expressed interest in participating in future evaluations and was enthusiastic about *CURIO*'s goals.

3.4.3 Discussion

The evaluation study generated promising results. Response from the students was generally positive, and their feedback provided valuable input at that stage of the game's development. The students were engaged and focused during the game session. In addition, *CURIO* facilitated discussion between the students and appeared to stimulate thought on the presented topics.

The teacher's feedback suggests that *CURIO* is a good fit for new educational approaches in the Netherlands that focus on experiential learning. The quality of the questions asked by the students increased over time, indicating that it is best to use the *CURIO* gamekit for at least half an hour. Repeated use of the gamekit may also contribute to students learning to ask more complicated questions. The initial test suggests that *CURIO* can meet its primary goals at its inception. It can be a helpful tool for teachers in structuring conversation around a new topic, stimulating students to take on an inquisitive mindset around a topic, and giving teachers a better understanding of their students' prior knowledge and assumptions.

While these initial results are positive, further validation of a concept like *CURIO* is necessary to assess its usefulness to teachers and students. The final version of the game kit requires testing in different schools that follow various teaching methods. Depending on the environment, *CURIO* may not fit well with different teaching styles.

It is also essential to understand the *CURIO* game kit in the way it has been intended: as a tool that teachers can use to support their teaching efforts, using infrastructure that they have at their disposal. The school where the evaluation study took place was chosen partly due to its existing integration of technology in the classroom. This setup is what many schools aspire to, as is evident by "one tablet/laptop per child" initiatives. However, this technological infrastructure is far from the standard in all schools.

It was a welcome find that *CURIO* appears to fit well with the teaching methods employed at the school where the evaluation study took place. However, different schools and teachers may provide varying opinions on *CURIO's* usefulness to them. The *CURIO* game kit does not propose that technology in the classroom intrinsically improves the quality of education but instead aims to provide valuable content for classrooms that utilize technology to support teachers and students. Teachers that categorically dismiss the use of game-based technology will find as little use for the gamekit as those that expect it to provide educational value without their involvement.

The results of the evaluation study inspired several more changes to the game kit. The number of default sub-topics per game session was reduced to limit the overall game length. Teachers were also given more control over certain aspects (e.g., team composition and session length), and students were given increased interactivity options when the teacher evaluated student questions. A brainstorm session with the students resulted in the endgame and post-game activities, described in section 3.3, which provide a natural conclusion to the session. These additions tone down the competitive aspect, and students receive individual rewards for their questions. Several additional minor changes included adjustments to timing and visual feedback to clarify what students can do at a given moment in *CURIO*.

3.5 Using CURIO in class

This section presents guidelines for using *CURIO* in the classroom based on the results of the evaluation study and the design intentions behind the application. Notably, these come with the caveat of putting interested educators in the position of testing out a new tool. Nevertheless, they should be considered the best available evidence for how *CURIO* can support teaching. Apart from aiding educators, these guidelines can support developing and researching other GBL projects intended for similar circumstances and environments.

I. Game Flow: Ideally, each game round in a *CURIO* session is followed by a discussion between the teacher and students. The teacher can refer to inquiries made to explain aspects of the related topic. Especially in large classes, it can make sense to address the most frequently occurring questions and ask students to argue for what answers might be possible and why. *CURIO* makes it easy to extend or skip individual phases in a game round as teachers see fit. Teachers are encouraged to use that functionality to support their teaching efforts.

II. Timing and Time Investment: The *CURIO* game kit is best suited for introducing new topics where teachers can expect to find some pieces of pre-existing knowledge among their students. Topics that are radically unfamiliar to students might lead to the formulation of fewer, too general questions. On the other hand, topics that are very specific or well-understood might lead to questions that are less likely to be actually on the mind of students. Sessions involving *CURIO* should not occur too frequently, as the process of formulating questions is mentally exhausting and should be followed by actually addressing some of the posed inquiries. Teachers should also not rush through a session but rather implement breaks as teaching and playing are interdependent activities when using *CURIO*. Teachers should schedule 1-2 hours for their first session with *CURIO* and should make sure that students can anticipate the ending if a session ends before exploring the entirety of the game board.

III. Managing Expectations: *CURIO* should not be framed as a reward in itself and should not be used as such by teachers. While it features elements that are intended to feel rewarding, it is an activity that demands time and concentration from both students and teachers. This demand makes it a poor choice for concluding an already intensive teaching day. Teachers will need to be open to the possibility of using games as a legitimate medium for education and not solely as a source of entertainment. This also means leaving enough time for the conclusion of the game, where students get to collectively defeat the game's symbolic antagonist and decorate their ship as a reward.

IV. Preparation: While care has been taken to keep organizational tasks in the game as simple as possible, teachers are advised to prepare their session with *CURIO* in advance. A well-prepared scenario will give teachers a better idea about what to discuss between the individual game rounds and ensure that the questions that students come up with are relevant to what is supposed to be covered by the curriculum. Class lists are also best created before a session takes place. For the very first session, teachers will also have to explain how students connect to the teacher's computer.

V. Openness to Questions: *CURIO* gives teachers complete control over what they deem good questions. During early focus groups, teachers remarked that the phrasing of "rejecting" a question sounded harsh. While students are not directly informed about having their inquiries rejected, the blunt language for not accepting a question is by design. Teachers are invited to be generous about what is a good question, as the process of coming up with questions is demanding. Whether or not to discuss a question in class remains up to the teacher's discretion. Rejection of inquiries is intended as a measure reserved for inappropriate behavior rather than an evaluation of student performance.

3.6 Conclusion

The main research question guiding this chapter was: How can a game facilitate conceptual exploration? It then explored this question through a design case study of a game-based learning application, the *CURIO* gamekit.

Existing game-based learning tools generally focus on imparting and testing content-specific knowledge. Secondly, they often exclude the teacher from the play experience. *CURIO* addresses these issues by involving teachers as active participants, helping to structure discussions around a new topic, and gathering data for teachers to shape upcoming classes.

For the context of this chapter, however, *CURIO*'s most important contribution is that it encourages students to adopt an inquisitive mindset. It does so by leveraging existing technology in classrooms while allowing for various technological solutions that do not require specific hardware or external infrastructures (e.g., an Internet connection).

Results of the evaluation study suggest that the design of *CURIO* can support teaching efforts in the classroom *(answering RQ1)*. It also indicates that students become more curious about the game's topics *(answering RQ2)*.

It should be noted that the study did not test whether it was more effective than involving non-game teaching material. Further evaluation is also required to show whether *CURIO* assists teachers and students in tackling a new topic. Future efforts, for instance, may involve using *CURIO* at the start of a project and evaluating students' behavior over an extended period. Similarly, further examination will need to show whether *CURIO* is considered helpful by teachers of different backgrounds and educational settings (e.g., varying by school and country). Answering these questions was outside the scope of this chapter, and the author's involvement with the project ended once the development and evaluation study had concluded. Upon finishing the project, discussions were taking place with the Malta Ministry of Education about integrating *CURIO* in classrooms.

The chapter illustrates how a game can be created focused on a particular type of curiosity, i.e., conceptual curiosity. It also shows that this is a complicated task even when focusing on a particular type of curiosity with a clear behavioral expression (i.e., asking questions, as derived from focus groups with teachers). It requires careful managing of the "information gap"; ensuring that there is enough information to stimulate thought but not so much as to take away all sense of wonder. In *CURIO*, this task is primarily delegated to the teacher as the "game master" who provides topics and leads intermittent discussions. If such considerations were not left to the teacher, they would fall to the game and/or content designer of the GBL artifact instead. Additionally, multiple other forms of curiosity also entered the design space, as explained in section 3.2.2, to increase the chances of eliciting the players' curiosity.

CURIO forms an example case study that shows, plainly and transparently, how a game can function to elicit conceptual curiosity, thus answering the research question. In addition to being a potentially beneficial GBL application, *CURIO* may also be used as a tool to further examine the balance required in structuring information to make optimal use of the “knowledge gap” by performing additional studies with different scenarios. Another contribution of this chapter is in describing the development complexities of a GBL artifact, a topic that will be further explored in Chapter 8. Most importantly, it shows how developing for a single, specific type of curiosity is a complex task, even in a relatively simple game, and one that involves design decisions aimed at triggering various forms of curiosity. In order to better understand various forms of curiosity and how they are elicited through game design, it is thus beneficial to take a broader perspective on video games and their design, as will be shown in the following chapter.