ArQuest: Augmented reality in education

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ABSTRACT
This paper describes the design and development of arQuest, an augmented reality-based questing system for education. Students use the arQuest app on their mobile devices to seek, solve and create their own quests; thereby expanding the classroom and promoting learning through creation. The design process pursued a technology-driven approach with methods employed from human centered design, and resulted in three prototypes: a storyboard, a system diagram, and a mobile application demo. These were ultimately presented and demonstrated at the IDXPO exhibition of 2015, dedicated to projects exploring mixed reality in education.

AUTHOR KEYWORDS
Education, augmented reality, gamification, location-based

ACM CLASSIFICATION KEYWORDS
H.5.1 Multimedia Information Systems: Artificial, augmented, and virtual realities

INTRODUCTION
This report documents an interaction design project exploring how augmented reality can be used in education. The result developed was arQuest, a system that uses augmented reality and gamification to supply novel opportunities for learning in school. The project followed a technology-driven approach and was conducted in cooperation with the high school Kattegattgymnasiet in Halmstad. Following is a description and discussion of the design process and the possibilities for continued development.

The Concept: arQuest
This section covers the purpose of the system, its use, as well as its technical details.

A game for students, a tool for teachers
The arQuest concept adds a digital layer of hidden quests to the regular school experience. Using the arQuest application on a mobile device, this content, which is invisible to the naked eye, can be viewed and interacted with in order to solve quest challenges. Some quests are intended for individual students, others require that the student completes them with a classmate or even members of other classes, resulting in "co-opetitive" play: simultaneously competitive and cooperative.

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The students are the "players" in the system and join the game as a part of their class teams. To play they can either consult the *Quest Giver* hub point, receive quests from their teachers, or even find them around the school. For students who are instead motivated by being creative, they can contribute their own content for other students to find and complete. The teachers, meanwhile, can be likened to game masters, the directors of the game. Their role is to create quests, manage the rules, organise the game sessions as well as moderate the system.

Variation and cohesion
A game of arQuest runs throughout the school year, with the regular quests being accompanied by seasonal events and themed week-long competitions. Points are accumulated by each class and a winner is crowned at the end of the school year. This will create a sense of cohesion by tying the year together into a unified experience, as well as offering unique opportunities on special occasions.

The reward system categorises quests into those related to the curriculum, and those that are not. Curricular quests are challenges that give students an opportunity to influence their marks, and reward students with the larger and more valuable green *intelligems*. Of course, there are also quests of a lighter nature created by fellow students: opportunities for practice, a deeper understanding or just plain fun, which reward students with a smaller *clevergem* upon completion.

The Framework
Technology-wise, the aim of arQuest is to make use of devices that students and teachers already possess. The application runs on a regular smartphone, and is the window through which students interact with the system. The second user group, teachers, use their desktop or tablet computers to update and maintain arQuest. The *Quest Giver* and quests themselves are identified with an iBeacon device combined with visual markers that can be detected using the phone's camera. These devices, which provide the range and location detection functionality required to find the quests, are the only additional technology included with the system.

BACKGROUND
ArQuest leans heavily on existing concepts in the sphere of pervasive and location-based games, and takes inspiration from house systems. Each of these concepts are briefly discussed below.

Location Based Games and Experiences

ArQuest falls loosely under the umbrella of pervasive games, an area where location-based experiences proliferate. Most familiar is Geocaching, where items are hidden and placed on a map using GPS co-ordinates. Similarly, Rider Spoke [6] invites cyclists to leave recordings for others of "stories from their lives" while exploring the city at night. In Repudo, users leave "digital objects" [5] for others to find and move to other locations.

What differentiates arQuest from these projects is that quests are situated within the school building, meaning that GPS coordinates are unreliable. The team has therefore sought to exploit seamful design in their approach to their problem, using this unreliability "as a design resource rather than as a problem to overcome" [8] to make the hunt for quests more enjoyable. In Geocaching, the hunt is enhanced by the fact that GPS location only locates the cache in two planes, but not in the vertical one. Similarly, students are alerted to nearby quests using location-based technology, but find them by manually searching.

School Houses

Inspiration for arQuest came from the house systems in some other countries, such as the United Kingdom. Such systems have been reputed to foster a "significant impression of camaraderie, a sense of belonging, and a shared commitment to one another" [2] within the houses, even between members of different classes. The designers sought to build their idea around this, but to instead use the class unit.

Similar Products

There are few products that occupy a similar space to arQuest. One of the more significant examples, which also proves that there is merit to pursuing the arQuest concept, is Quest To Learn, an initiative where games take a central part in the schools teaching activities, teaching students important lessons about trying until you succeed and fostering collaboration in order to accomplish your goals [7]. Another example can be found in the augmented reality application Hidden Park, where children explore their local park to find hidden elements, exemplifying the appeal of a treasure hunt.

METHODOLOGY

In this section a short description of the different phases and methods employed during the project is given.

Ideation

A concept set was generated during an initial brainstorming session and ArQuest was selected as the most promising idea following a presentation of this set. Going forward, the team expanded the concept, using a series of sketches of scenarios, interactions and components of the system. The team also bodystormed the system by creating a playful low fidelity prototype where a game master took photos of different locations that players had to find. This was done to explore possible content for the game, as well as understanding the appeal of the hunt.

Background Research

Research was conducted to gather a deeper understanding of the design domain, the users and possible technical solutions. This included investigating similar projects and available technology for tracking location in an indoors environment, such as Google Tango and the final solution decided on: iBeacon.

User Research

Users were brought in on two occasions, to elicit requirements from teachers and students respectively and to evaluate the design. To evaluate the initial concept, three high school students were approached in their natural element, in a short one-on-one semi-structured interview via online text chat: a "chaterview".

The team also conducted a study visit to Kattegattgymnasiet. As the client, the team sought familiarity with the school grounds, exploring them and taking pictures where appropriate. Here, they also conducted a participatory design workshop with a group of seventeen students. The workshop began with an exercise intended to mimic the gameplay of arQuest, where students invented questions for each other, and were scored on whether they were answered correctly. Students were then interviewed on their impressions and asked for how to improve the system for students.

The team also conducted a smaller interview with two teachers, and a group interview with eight. Emphasis here was on how quest maintenance can be made simpler, and what place arQuest has in teaching. Both interviews and workshop were recorded and analysed for valuable insights, which were used for evaluation of the concept and refinement of the system scope.

EXHIBITION AND PROTOTYPES

The design process culminated in a series of prototypes of the product to be used as evaluative tools at the IDXPO exhibition: a system diagram, a storyboard and a demonstration application.

System Diagram

The system diagram shown in Fig, 1 was produced to make the system more concrete, comprehensively specifying the system as a whole in terms of its technical components, actors and possible actions.

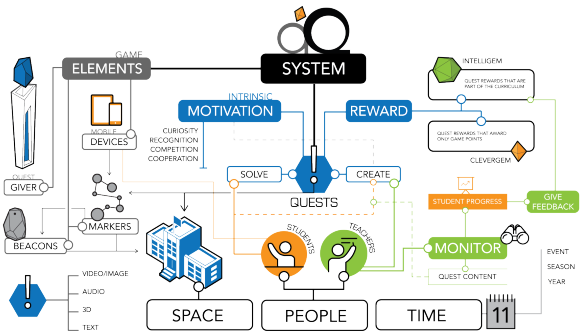

Figure 1. The system diagram.

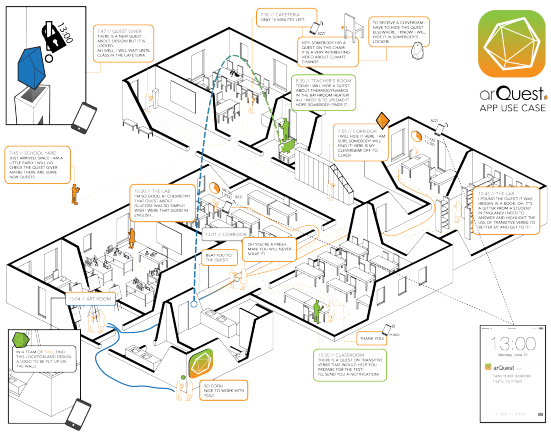

Figure 2. The storyboard.

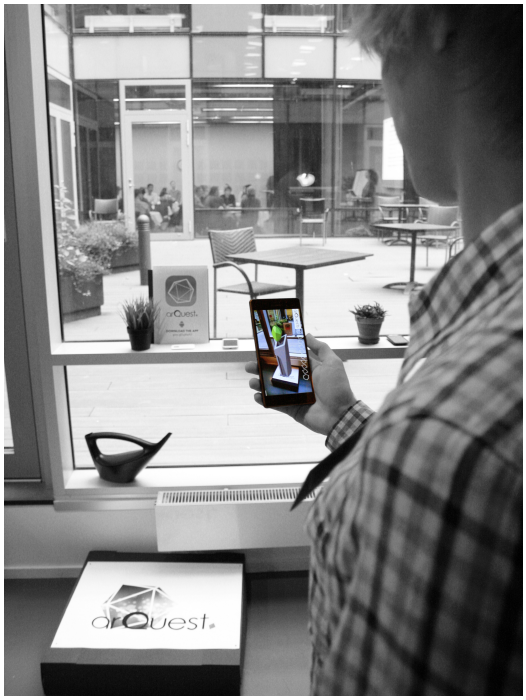

Figure 3. The demonstration app.

Storyboard

The storyboard (shown in Fig. 2) presented examples of usage from the perspective of both students and teachers. During the exhibition, this was the most utilised method for presenting the full system functionality, before inviting attendees to try out the demonstration app.

Demonstration App

The demonstration app (shown in 3)was developed as a simplified version of the full system, produced using the exhibition hall as a metaphor for the school grounds. Attendees were invited to embark on an quest to find questions hidden in each of the nine other exhibits. The final arQuest was to provide feedback on the idea, sending a short, anonymous sentence on their experience to a dedicated Twitter account.The app was built for Android, using a combination of the Unity platform and Vuforia Augmented Reality framework.Graphics from the other exhibits were used as Fiducial markers, and a question associated with that exhibit was shown when found.

RESULT

The following sections discuss the final design based on the value it presents, and feedback from the exhibition.

Value Proposition

As the concept developed, the team sought opportunities within the research space that could be addressed using the system. The values of the system thus co-evolved with the system itself, and related to teachers, students and school management.

For Students

ArQuest aims to provide an additional source of motivation to enhance learning, and allow students to study actively. The inherently interesting aspects of the experience are key, rather than external rewards. As a result, in arQuest all five of the key aspects of "intrinsic motivation" are present: curiosity, challenge, competition and cooperation, control, and recognition [3]. ArQuest also provides the means to learn through creation. This is discussed by Kemp et al, who pose that "the act of creation challenges the student, focuses their attention and gives them something concrete to aim for" [4].

The system also provides further benefits to students. The co-opetitive aspect encourages students to meet and work with new people in new and interesting circumstances. It binds class units together more coherently as all members of the class work towards a common goal. Finally, it fosters exploration of the school environment and forming a more cohesive bond with the school grounds themselves.

For Teachers

ArQuest expands the classroom, offering teachers a further means to examine students with questions situated in an appropriate context. Chemistry questions, for example, can be hidden in the school laboratory.The system provides a low threshold of entry with plenty of room for experimentation. This provides the opportunity to engage students in a new fashion, and to target quests specifically towards certain students or topics. In addition, teachers are given a means to reward initiative taken by students, both in seeking out and answering existing quests, and in creating questions themselves.

For School Management

The only additional purchases needed are the iBeacons used to locate and interact with the quests. Furthermore, most of the arQuest system exists only in the digital dimension, and as such will take up minimal real world estate. Nor will applying the system in a school require any large changes to the current spaces. Integrating it into the school environment is thus both cheap and simple.

Evaluation

The prototypes used at the exhibition were generally well received. Most testers of the demonstration app were fully engaged in finding the hidden questions, and found it to be an interesting way of touring the different stands. However, they expressed frustration at how difficult some quests were to find, not knowing where to look for them. As location features are a goal of the final system this feedback was not deemed relevant at the current stage. It was suggested that this could be an effective way to explore the confines of other exhibitions, such as in a museum, showing clear signs of the feedback being affected by the context that the prototype was presented in. Consequently, much of the feedback received at the exhibition was not conducive to improving the product itself, but could be used as a way of motivating potential investors.

DISCUSSION

In this section the design process will be examined and discussed.

Technology Driven Design

The arQuest concept was conceived very early in the design process, born from the thought experiment of applying augmented reality technology to education. As such, the concept was not grounded in knowledge about the domain or the intended users, but rather in how to apply a certain technology, so called "Technology Driven Design".

If one follows current design trends, it could be argued that this is a backwards approach to design. From the Human Centered Design viewpoint that IDEO encourages [1], this process lacked the valuable inspiration phase to base design decisions on, and proceeded straight into ideation. Instead of finding a solution to an identified problem, in this project the team instead proceeded from an idea to finding an opportunity for improvement that it might address.

This was appropriate to this particular project, since as past high school students, the domain was well known to the design team. Going about the process in a similar manner when designing for other domains could be less successful, and even though the approach was successfully applied in this project, one must always be careful not to overestimate one's knowledge of the domain and the intended users.

What this approach did provide, however, was a quick and cheap design process, leading to a fast result with which to attract potential investors. Though the initial offering could have been grounded more in user research, this could be addressed once provided with an adequate interest and economic means to pursue the project to its completion.

Designing a Complex System

The final design is quite similar to the initial concept, which suggests that more could have been done to expand on it. Part of the problem was that the idea itself was difficult to concretise. From the collected feedback it was clear that there was great potential for a questing system within schools, and that it could be applied in many areas. The greatest challenge therefore was to establish what the full scope of the system was, hence the need for the system diagram.

Going Forward

The user studies conducted, while limited in scope, show that there is an interest in a system like arQuest, giving confidence that the concept is worth exploring further. The teachers consulted expressed enthusiasm for a teaching tool that would let students learn outside the classroom, and within a competitive context. The prototypes were also received well at the exhibition, but due to their limited nature, do not represent a fully defined system, nor were they given in the appropriate context for evaluation.

Nevertheless, there is potential for adapting the concept to be used in other environments, such as museums. This is based on the feedback expressed during the exhibition on the demonstration prototype. The simple fact that the game was widely appreciated when demonstrated in the exhibition setting also suggests that arQuest could work in other fields than education.

A valuable next step would be to conduct tests to explore the viability of teaching using the arQuest approach. What would the benefits be of having students search for challenges and completing these assignment-like quests around school, and does it work in practice? More research is also needed to establish how to keep students invested in the system, both for learning and creating new content, with field trials being a logical way to assess this.

The interface for the teachers presents a problem in that their time is valuable and interactions with arQuest need to be efficient, and yet flexible enough to encompass all subjects taught in high school. The team therefore wants to develop a strongly modular structure and interface for the application, based on a large-scale assessment of possible topic areas.

The place of augmented reality in the arQuest system is another area which warrants further review. The main purpose for which it was included was to visualise subjects that can be difficult to grasp in two dimensions. Representing it this way improves student engagement and apprehension of knowledge, but this is not a fact exploited to its full advantage in the system as it currently stands.

From a technical standpoint, locating the quests within the confines of a building continues to be a challenge. There are several technologies available to support this feature of arQuest, including the iBeacons discussed here, and Project Tango. The team would need to further investigate these and other technologies to establish the way forward.

CONCLUSIONS

Introducing augmented reality to education does not need to be an expensive endeavour, nor does it have to require radical changes to current practices. Stakeholders have expressed a great interest in augmented reality, as it can offer new ways of visualising curricular content, let students learn in an active manner and to interact with each other in a new and educational way. The arQuest system has thus presented a novel and flexible way to make use of the already existing technology in school in order to provide an expanded experience.

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