Let the Play Set Come Alive: Supporting Playful Learning through the Digital Augmentation of a Traditional Toy Environment

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***Abstract*— The Augmented Knight's Castle (AKC) comprises traditional play figures and scenery embedded with radio frequency identification (RFID) technology to enhance user experience by triggering various forms of audio output. In this paper we present the results of a user study with over 100 children to evaluate the AKC in terms of playful learning, compared with an identical, non-augmented version. Findings suggest that children who played with the AKC remembered facts about the Middle Ages that were presented to them in the form of verbal commentaries, both immediately after the play session as well as in a post-test two months later.**

Keywords- Augmented Knights' Castle, User Study, Children, Augmented Toys, Playful Learning, RFID Technology

I. INTRODUCTION

Augmented toy environments are play environments that combine the physical world with the virtual world. By equipping traditional toys with modern communication and sensor technology, it is possible to extend the virtual world to real-world objects and consequently offer new play and learning experiences, for children (e.g., [1][3][7][8]).

The Augmented Knight's Castle (AKC) is a pervasive computing Playmobil® medieval castle play set which enriches the children's pretend play by using background music, sound effects and verbal commentary of toys that react to the children's play [6]. Using radio frequency identification (RFID) technology, we are able to detect play figures in the play set and utilize this information for appropriate audio output.

RFID technology operating in the high frequency spectrum (typically, at 13.56 MHz) features a well-defined read range. This enabled us to adjust the size of so-called *active zones* to the physical layout of the play set (see Figure 1). For example, the drawbridge was observed using one 10x10cm antenna, eight 10x10cm antennas covered the courtyard of the castle and the tower platform was equipped with one 3x4cm antenna. In total, the play set featured nine active zones (9 readers, 3 multiplexers, and 22 antennas).

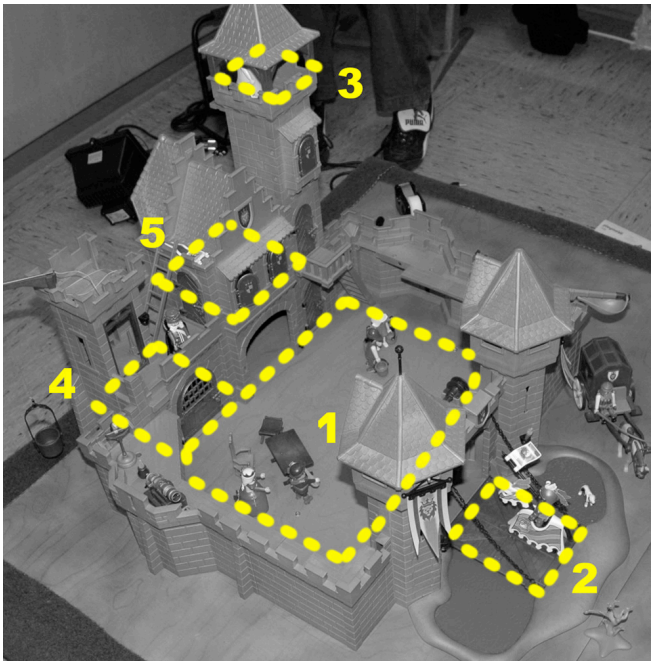

Figure 1. The active zones of the king's castle: inner yard (1), draw bridge (2), castle tower (3), castle dungeon (4), and throne room (5). The dragon tower and the fairy well had similar active zones.

The antennas were either attached to the toy buildings or to different types of floor elements to detect the presence of toy pieces in their proximity. RFID tags of different sizes were attached to or incorporated into the pieces of the play set to uniquely identify and consequently associate virtual content with them. Each figure was equipped with several tags to maximize probability of detection.

For each figure we recorded a number of different verbal commentaries (e.g., "I am the king."), sound effects (e.g., howl of the wolves), and/or educational content (e.g., "When not involved in battles, knights often went hunting."), with a different voice picked for each figure.

Whenever a figure was placed in one of the active zones, one of the recorded sound files was played: while in most cases it was played randomly, we also included some sound effects that were played at a particular location and/or with special characters (e.g., if the black knight is on the drawbridge, a voice says "Look out, townspeople, the black knight is entering the castle"). In total we recorded over 200 sounds for 30 figures.

Figure 2. The Knight's Castle (left) and the Augmented Knight's Castle (right). The two play sets were identically designed and equipped.

Being built from a traditional toy set, the AKC offers the opportunity to explore the differential effect of an augmented compared to a non-augmented play environment. Thus, a comparative study was conducted using the AKC and an equivalent traditional (non-augmented) play set – the Knight's Castle (KC) – to evaluate the effectiveness of the environment for supporting playful learning (see Figure 2).

One particular goal of the user study was to explore the value of an augmented play set for conveying educational content. This paper presents the details of the user study and discusses the results and findings, focusing on statistical data collected, and data from interviews with children following their play experiences with the AKC and the traditional KC.

II. METHOD

A. Participants

The user study was conducted in an elementary school in Germany. Participants were 103 children, 55 boys and 48 girls, aged 6 to 10 years from the first to the fourth grade (see Table 1). The children in each class were divided into groups of two or three, resulting in a total of 39 groups. Children were grouped with their classmates to counteract any awkward "getting acquainted" phase and facilitate the children starting to play right away. For our later analysis, we divided children into younger (Grades 1 and 2: 6 to 8 years) and older (Grades 3 and 4: 9 to 11 years).

We were also interested in the opinions of the seven teachers of the school on both the AKC and the role of playing with different media for children.

B. Procedure

Each group played either with the non-augmented KC, the AKC, or both. The groups that played with both play sets started with the KC and played with the AKC next (KC/AKC), or vice-versa (AKC/KC). Groups were distributed as equally as possible given time constraints of the school to fit the children's curricula.

Table 1. Overview of the grouping of the children. Test type refers to which play set(s) the children played (i.e., "KC" = played with KC only, "KC/AKC" shows the order of play).

Test type	No. of groups	No. of children				
		1st	2nd	3rd	4th	∑
KC	13	6	6	11	10	33
AKC	12	8	8	8	9	33
KC/AKC	8	2	4	5	3	14
AKC/KC	6	6	6	3	8	23
∑	39	22	24	27	30	103

The children played with the KC or AKC for approximately 35 minutes (see Figure 3), followed by group interviews with the researcher (see Figure 4).

Figure 3. Children playing with one of the play sets.

The children playing with both play sets had approximately 20 minutes with each set and then participated in the same interview process. The children were not given any particular instructions – we simply told them to play with the play sets as they would at home. Even the children playing with the AKC were only quickly briefed inasmuch that we demonstrated the modus operandi (i.e., how to trigger the audio feedback) to them once at the beginning. They were not instructed to attend to or remember information given by the figures.

In the interview session, children were asked about the kind of stories they had created (see Figure 4). This helped us to understand how the children played, but also enabled the children to overcome any shyness. The children were then asked questions relating to our research focus. We first elicited the children's views about the play sets (the results of this part of the evaluation are published in [5]).

Figure 4. Interviewing the children after their play session. During this part of the interview, children were asked open questions about their stories, play experiences, what they liked, what they disliked, etc.

We then asked four multiple-choice questions to find out if the children retained any of the information from the integrated educational content of the AKC (see Figure 5). The answers to three of the questions were provided in the verbal commentaries of the figures in the AKC play set ('given' questions, GQ), but the answer to the other ('new' question, NQ) was not, providing a control question to ensure there were no differences in knowledge of the period between children in the different conditions. Thus, only children in the AKC conditions had the opportunity to hear the answers to the given questions, and none of the children was given a chance to hear the answer to the new question.

- GQ1. What was the most important food in the Middle Ages? (Answers: bread, meat, potatoes)
- GQ2. What was the preferred leisure time activity of knights? (Answers: hunting, playing, painting)
- GQ3. How much was a sword worth in the Middle Ages? (Answers: 7 cows, 5 pigs, 2 sheep)
- NQ1. What was the royal color? (Answers: red, yellow, green)

The correct answer is shown here as the first alternative in parentheses, but order of answers was randomized for the children.

An unannounced delayed post-test with the same four questions was administered to 88 of the children two months after their play sessions with the AKC, to determine any longer term effects for learning. To this end, we handed the children a questionnaire with the same questions and answers. The children filled in the questionnaires in their classrooms under supervision of their teachers.

Figure 5. A child picking cards to answer closed questions regarding fun and educational content.

C. *Interviews with the Teachers*

We were also interested in the opinions of the seven teachers about both the AKC and the role of playing with different media for children. We presented the system to them and they then completed a questionnaire with the following five questions:

- How do you like the idea of the AKC in general?
- Do you consider the AKC to be suitable for conveying informal content to the children (e.g., figures tell about their lives and roles in the Middle Ages)?
- Do you consider the AKC to be suitable for conveying formal content to the children (e.g., the alchemist could tell them about chemistry or other natural sciences)?
- How important is it that children at elementary school age work with computers (for both gaming and working)?
- How important is it that children at elementary school age play with traditional toys?

The teachers could rate their answers each on a scale from 1 to 5, with 5 being the highest rating.

III. RESULTS

A. Playful Learning

As described above, we asked children two types of question: three related to 'given' information given in the AKC and one related to 'new' information not given, as a check on children's general knowledge of medieval life. There was an immediate post-test and a delayed post-test two months later. Percentages of correct responses for the immediate post-test are shown in Figures 6 and 7 for younger and older groups respectively.

1) Immediate post-test

An analysis of the proportion of correct answers for the given and new information, with age and play condition (KC, AKC or both) as between-subjects variables showed that – as might be expected – older children answered questions more correctly, $F(1,95) = 5.38$, $p<0.05$.

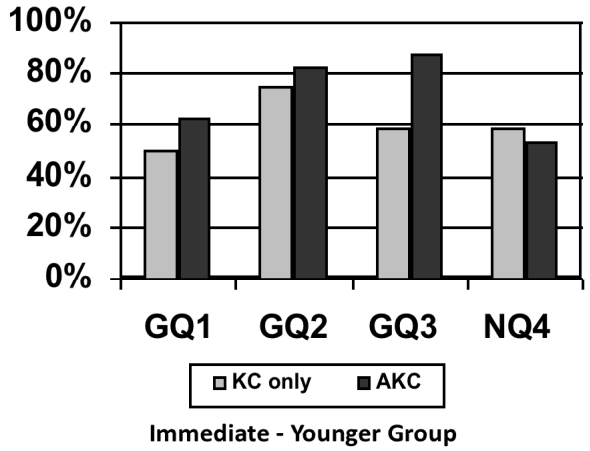

Figure 6. Percentage of correct answers for given (G) and new (N) questions for the younger age group during the immediate post-test. KEY: GQ1 = food, GQ2 = leisure, GQ3 = sword, NQ4 = colour.

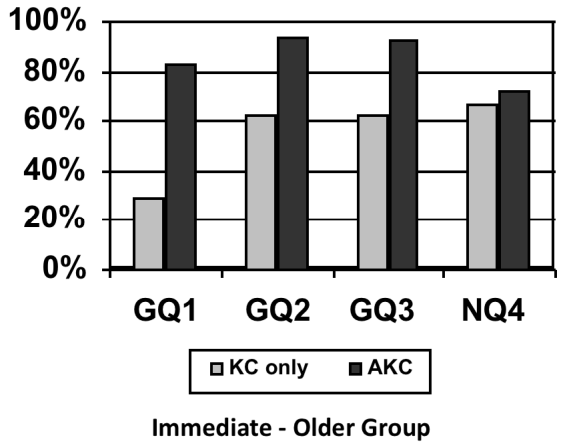

Figure 7. Percentage of correct answers for given (G) and new (N) questions for the older age group during the immediate post-test. KEY: GQ1 = food, GQ2 = leisure, GQ3 = sword, NQ4 = colour.

It also showed that 'given' questions were answered correctly more often than 'new', $F(1,95) = 8.53$, $p<0.01$.

More importantly, there was an interaction between play condition and type of question, $F(3,95) = 2.9$, $p<0.05$. A separate analysis comparing children who played in conditions with the AKC and those with only the KC showed that AKC experience produced better performance than non-AKC on the given questions (overall means of correct answers of 84% and 54%, respectively) but not on the new question which had not been covered in the AKC (means of 63% and 64%, respectively). Clearly, children using the AKC benefited from the audio information provided, even though not all actively attended to it.

2) Delayed post-test

Children were asked the same information questions two months later, and the results are shown in Figures 8 and 9.

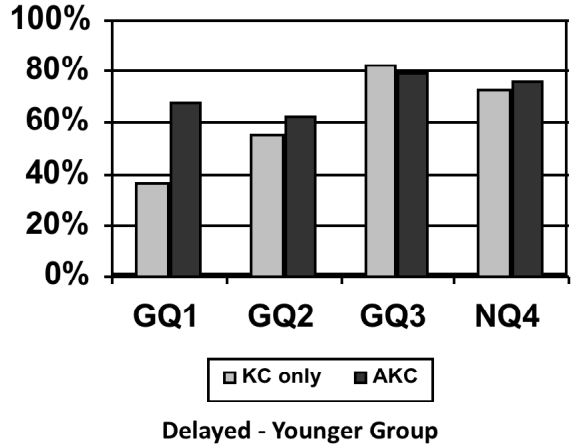

Figure 8. Percentage of correct answers for given (G) and new (N) questions for the younger age group during the delayed post-test. KEY: GQ1 = food, GQ2 = leisure, GQ3 = sword, NQ4 = colour.

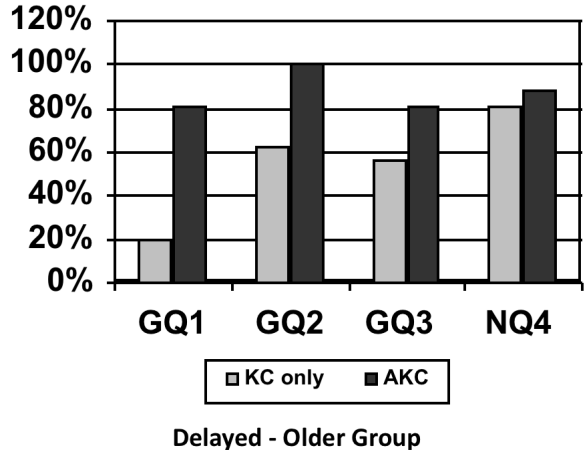

Figure 9. Percentage of correct answers for given (G) and new (N) questions for the older age group during the delayed post-test. KEY: GQ1 = food, GQ2 = leisure, GQ3 = sword, NQ4 = colour.

For the given questions, overall performance was slightly but not significantly lower than the immediate post-test, 69% correct vs. 74%, respectively.

An analysis of variance on the given question scores at the delayed post-test, with age group and testing condition (KC only vs. others) between subjects, showed that children who had played with the AKC still did significantly better than those playing with the KC only, $F(1,83) = 20.98$, $p<0.001$, 84% vs. 54%, respectively. Matter-of-factly, non-AKC children's performance was no better than guessing.

There was also an interaction between play condition and age group, $F(1,83) = 4.28$, $p<0.05$. The difference made by playing with the AKC was greater for the older than for the younger group. For a similar analysis of scores on the new information, there was an effect of testing occasion: performance regardless of age or play condition was higher on the second testing, 64% vs. 80%, $F(1,84) = 6.85$, $p<0.01$.

B. Children's play behavior

Before we invited the children to play with either set, we asked them several questions to gain insights into their typical play habits. To this end, we asked them how often they played with both traditional toys and computer / video games, respectively.

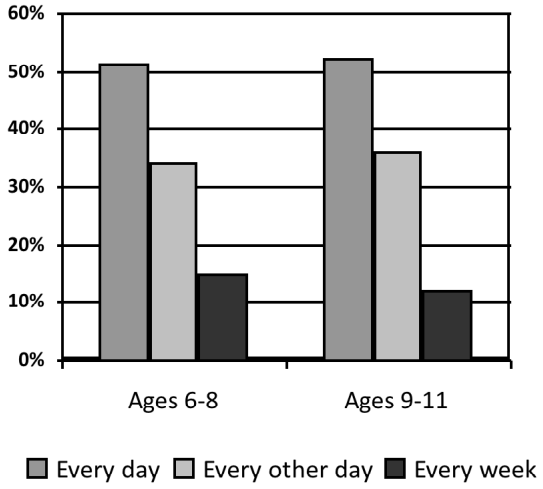

Figure 10. Overview of how often children play with traditional toys.

Both groups reported playing about the same amount of time with traditional toys, $X^2(2) < 1$, not significant, but the older group was more likely to play video games than the younger, $X^2(2) = 7.4$, $p<0.05$ (see Figures 10 and 11).

However, there were no differences in the amount of learning from the AKC between children who played more or less frequently with traditional or electronic toys: learning happened regardless of the extent of children's reported play experiences or their familiarity with technology.

C. Teachers' Opinion

Teachers' responses are shown in Figure 12. All thought traditional toys were very important (Q5) and that computers were also important but slightly less so (Q4).

They rated the AKC generally very highly (Q1), for both informal (Q3), and to a slightly lesser extent, formal (Q2) learning.

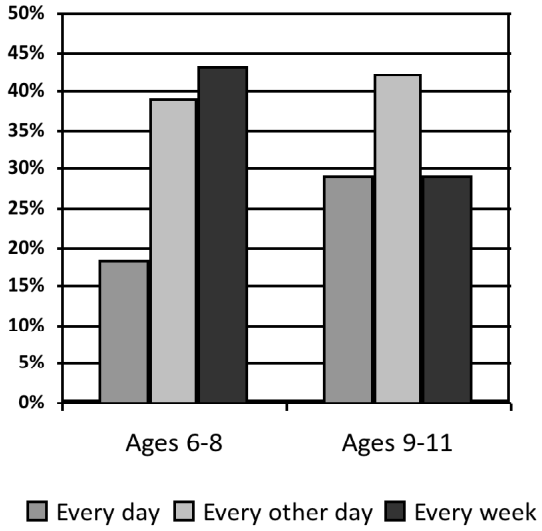

Figure 11. Overview of how often children play computer / video games.

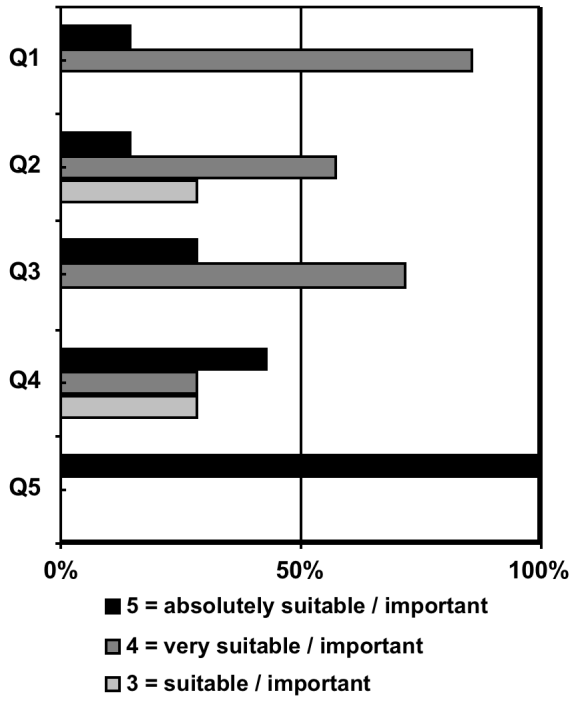

Figure 12. Percentage of teacher ratings for each question. Notes: N = 7. Ratings from 1 (completely unsuitable / unimportant) to 5 (completely suitable / important). Ratings of 1 and 2 were never given.
Q1 = How do you like the idea or concept of the AKC in general?
Q2 = Is the AKC to be suitable for conveying formal content?
Q3 = Is the AKC to be suitable for conveying informal content?
Q4 = How important is it that children work with computers?
Q5 = How important is it that children play with traditional toys?

IV. DISCUSSION

The most striking result of this study is that children experiencing verbal commentaries integrated into a traditional play set showed significant learning. This learning was not planned, but was incidental to the children's play. The technology in this study was presented in a low-key, informal way for free play, with no instructions to remember or learn. It is notable, therefore, that the children playing with the AKC showed very good retention of what they had learned after their brief play sessions. Children clearly attended to commentaries and information in the AKC. Interview data from post-play sessions confirmed this. Using the new vocabulary and speech patterns introduced (e.g., "My queen" or "jousting"), some children could repeat commentaries verbatim and almost all could reproduce the general essence of the content.

Because the audio output can be configured, by teachers or by the children themselves, it can be used to introduce new vocabulary, which the children can then imitate in the same setting, similarly to how mothers mirror and extend children's speech in the early stages of vocabulary learning [1]. We are currently examining whether the audio output is useful for stimulating speech in groups with language and communication difficulties, such as children with autism. Likelihood of a word being repeated is related to frequency of the sound being played and words are better remembered if spoken by a character than by an adult human.

Furthermore, the delayed post-test data showed that children experiencing the AKC continued to have an advantage in their knowledge even two months after their short experience. In combination with the interview data, this clearly indicates that children feel able to ignore or disregard augmented sounds and narrative (we investigated and discussed this in the first part of the evaluation [5]). In general, this suggests that augmented sound/narrative may have a powerful effect on children's information acquisition. It would be interesting to know whether factual knowledge contributes to a better conceptual and imaginative understanding of life in medieval times, which certainly merits further research in this area.

We also intend to further involve teachers and parents as they also have an expressed interest in creating and selecting appropriate educational content. Generally, teachers rated the play set highly and they were very interested in this approach of augmented toys, which seems to be more appealing than simply using a fully digital environment (i.e., a computer-based environment): while they noted the importance of experience with computers, they rated play with traditional toys much more highly.

Involving teachers and parents would require authoring and configuration tools, which we are currently developing. The idea is that these two user groups can integrate new content themselves (e.g., by uploading audio files or direct recording) and create corresponding rules in the play set (e.g., this sound file should be played whenever the king meets the blacksmith). Similarly, we are very interested in finding out how children would exploit the possibility to record their own verbal commentaries and stories.

Equipping traditional play pieces with pervasive computing technologies bears some potential for future play scenarios as they can be easily linked to the digital world: for instance, toys can keep a blog of the play activities they have been involved in, which can then be interpreted as auto-generated diaries. Having a child's room filled with smart objects that are capable of telling stories and giving information about themselves and "their view of the world" could be an enthralling, interesting and, most importantly, playful way of explaining the world to children.

This study is one of the earliest studies in the field making direct comparisons between digitally augmented and non-augmented equivalent environments. We set a challenging target, since the KC itself is a very engaging toy, and the AKC differs only in augmenting with context-sensitive audio. This is important work in order to understand more clearly the differences that technology-enhanced environments have in mediating interaction, and to enable a clearer understanding of when and how augmented environments can be best exploited to support learning.

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