Augmenting play and learning in the primary classroom

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ABSTRACT

In this article we present the design and study of *Save the wild*, a system designed to support augmented play and learning for children. *Save the wild* is an augmented reality (AR) based system with which children can interact by creating origami paper characters printed with fiducial markers that can be recognised via the webcam attached to the computer. The system aims to give students a level of awareness around problems with sustainability. As children make visible their origami creations to the camera, the system displays animated virtual characters that are attached to simple storylines that relate to sustainability and environmental consciousness.

We studied how *Save the wild* was used and interacted with by students in two environments: at a public exhibition and within a classroom. We found that the technologies that were used (fiducial markers) can be used to create environments that support multiple modes of interaction and different forms of engagement with educational content. The technology allows designers of these systems to augment physical play and activity without requiring new technologies to be introduced, rather using technologies already found within the classroom. We find that by using AR, it is possible to enhance play-based learning without it becoming focused on the technology – rather it augments and guides the learners' own narrative. We conclude with a discussion on how AR/marker technology can enable technology to create a more exciting interactive and social experience for young students while they are learning.

Categories and Subject Descriptors

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Human Factors.

Keywords
Interaction design, education, fiducial markers, augmented reality, physical computing, play.

1. INTRODUCTION
The use of technology in classrooms holds the promise of new interactions and experiences when learning. Emerging technologies offer teachers new possibilities to communicate with individual students, organise group activities, and monitor individual progress [1]. There have been a number of discussions about how best to use technology in classrooms that focus on content delivery, with the assumption being that schools will use technology in the classrooms to support the teaching of its content. There have been a number of innovative technological developments in the higher education and adult learning sectors that have been adopted on a large scale, e.g. MIT's open courseware, massive online open courses (MOOCs), online publication platforms such as iTunesU and Academic Earth, open online learning institutions such as CodeAcademy and Khan Academy. However, technological initiatives designed for, and relevant to, primary school classrooms (some of which we will review in the next section) are still a long way from seeing a similar scale of widespread adoption. When we visit an Australian primary classroom today, we are not yet met by a seamless integration of technology as a tool for daily learning. Infrastructure (such as numbers of computers in the classroom and network connectivity) can vary widely from school to school, as can individual instructors' familiarity with teaching with technology. For most publicly funded primary schools, the technological revolution is one still waiting to happen.

We are interested in how to design interactive technology so there will be new values added in learning and play. This study is a continuation of our previous work - Discovery Table [2], where we investigated the design of augmented artefacts to support learning in a preparatory classroom. In the original study, we found that students like to move back and forth between the activities in the classroom and that they like to bring something physical with them to show to teachers and friends, extending the learning process away from the installation. We also found that new technology itself can be intimidating for teachers if they are not familiar with it. From our findings, we decided to explore the potential for the design of augmenting play that is already an integral part of the classroom through the use of existing technology already present in the environment (desktop computers). We focused on a specific activity (creating origami to learn about sustainability), which is a physical hands-on activity where students could keep their artefact, carry it with them to a computer and continue to play with it. We wanted to explore how we could augment this activity, to create a more intuitive and seamless use of technology in the learning context.

2. BACKGROUND
Our work is informed by previous studies that have deployed new technology within classroom environments, considering the unknowns of existing infrastructure within the classroom. In particular, we are interested in technologies that can enhance learning and discovery through the use of artefact detection and augmentation (Augmented Reality).

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2.1 Classrooms and Technology

Technology has had an important impact on activities within the classroom, with the aim to support both teachers and learners within the learning context. Traditionally, technology that is used within the classroom consists of commercial off the shelf (COTS) systems (such as Desktop computers), which are deployed into the learning environment without a clear understanding of their purpose [3]. This can be attributed to a number of factors, in particular disconnect between the design of the technology and the learning activities that are already taking place [3].

Most often, these COTS technologies are poorly introduced to the students, and also poorly supported by teachers. This means that students are not only tasked with learning the practicalities of the technology, but also having to make the connection between the technology and the learning activities being presented by the teachers [4].

Balaam *et. al.,* [5], when developing the "Subtle Stone" - an affective technology which reacts to a child's emotion - found that there are specific needs for technology to support the learning environment, and that there "is little prior work to draw requirements for the design of such technologies". Hew et. al [6] explore the issues of developing and deploying technologies into the classroom to support the learning environment. The authors suggest that there are six areas that should be paid attention to when integrating technology into learning environments:

1) Resources

2) Institution

3) Subject culture

4) Attitudes and beliefs

5) Knowledge and skills

6) Assessment

These areas highlight that it is not the technology itself that is problematic in the classroom context, but the relationship between the technology and the context. This is not to suggest that the use of technologies in classrooms is uncommon, Smeets [7] found that 93% of teachers surveyed had implemented some form of technology integration into learning, but rather that the technology is being used for skill based learning, as opposed to supporting deeper levels of learning. This suggests that to improve the use of technology within classrooms, teachers should be educated on methods in which they can adapt existing technologies to support their learning structures purposefully, rather than treating technologies such as computers as isolated activities.

Cox [8] found that teachers are most interested in technologies that help improve learning by making it more enjoyable for both the students and themselves. A popular way of achieving this is to use technology to support narratives that are used to help teach subject matter, giving them real-world reference to more abstract knowledge. Bers et al [9] developed SAGE, a system that allows students to create their own stories within a configured space. The learning focus of this system is to support children in the exploration of identity and communication..

Other work suggests that there are benefits to creating technologies that allows for multiple children to learn socially and use it collaboratively. KidPad and Klump [10] are systems that have been explicitly designed to facilitate collaboration between students, without forcing a specific method of participation. "We introduce an approach to the design of shared interfaces that involves subtly encouraging children to explore the possibilities of collaborating, without forcing them to do so". Billinghurst [11] suggests that by providing a common workspace, students have the ability to better collaborate. "In a classroom setting, students work together better if they are focused on a common workspace. Yet this is difficult to achieve in computer-based education".

2.2 Augmented Learning

An approach to designing human-computer interaction that has become popular in the last decade is the concept of Augmented Reality (AR). Azuma [12] defined AR as "a variation of Virtual Environments (VE), or Virtual Reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects superimposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it" Azuma [12]. This method of augmenting a physical environment is commonly used in settings in which the environment contains an existing purpose to support an activity – such as a classroom, museum or airport.

Many studies have been conducted which explore the possibilities of augmenting artefacts to support learning [2,13,14,15]. By making the common or everyday objects more interactive and engaging by incorporating surprises or information teases, the student learners are encouraged to continue their search for more and new information. Billinghurst [11] discusses the importance of physical objects within a classroom setting, "in educational settings physical objects or props are commonly used to convey meaning. Physical objects support collaboration both by their appearance, the physical affordances they have, their use as semantic representations, their spatial relationships, and their ability to help focus attention."

Augmented Reality consists of two aspects - the physical object being interacted with (which may include a marker for recognition) and the technology, which detects the physical object and augments it (though a combination of display and sound). We suggest that there are two primary methods of Augmented Reality: Situated AR - where the technology is situated in the space (such as projecting onto a wall), and Mobile AR - where the technology is portable, and held by the user (as shown by popular Augmented Reality smart-phone applications such as Google Goggles). The difference in these two methods is primarily based on how the user interacts with them. Do users carry physical artefacts to the technology? Or do users carry the technology with them and use them as a portal to the AR view?

Table 1. Methods of Augmented Reality

Method	Mobile AR	Situated AR
Mobile Component	Technology	Object
Limiting Factor	Concurrent users	Existing infrastructure
Object Considerations	Easier to design for if not portable – can assume its place within an environment	Must be portable and tangible
Interactions	User walks to the object of interest	User carries the object of interest into the augmented space

When designing AR within learning environments, an essential consideration is the existing infrastructure required. Mobile AR (where the technology is portable) does not have the same degree of reliance on the existing infrastructure embedded within the environment; however there are likely to be issues of scaling in settings such as classrooms (the number of devices required, or wireless network bandwidth). A major limitation with Situated AR is that the design of augmented artefacts typically requires technology such as projectors or cameras to be pre-installed for the interaction to occur. In primary school classrooms this can be troublesome, as there are continual changes in the physical configuration of the classroom. Most work that has been seen recently within these contexts has utilised the Mobile AR method. For example, Law and So [16] discuss the Maths Trial, where students walk around the augmented neighbourhood, discovering and solving Math problems. The authors however recognise that while QR codes (mobile AR) have thus far been successful within classroom environments, it is still an area for further investigation in research.

While Situated AR has historically required custom-built infrastructure within the environment, there is now an opportunity to leverage off the shelf computer equipment to support AR. Desktop computers are now capable of performing object recognition out of the box (using a built-in web camera). Screen sizes on these computers, while not the size of projectors, are becoming large enough to provide a collaborative viewing experience. Thus, we feel existing technology within classrooms may have potential to be adapted to support AR interactions for smaller groups.

A major consideration to consider for the method of Augmented Reality is the affordances provided by the objects themselves. In environments such as a museum, direct interactions with physical objects may be discouraged – to avoid damage to the artefacts. Coilfi et al [15] discuss the use of Mobile AR (using RFID tags) to interact through technology with physical objects through mobile technology. However in classroom environment activies, where physical interaction with objects may explicitly be encouraged, Situated AR has the opportunity to provide a more seamless integration of existing physical artefacts without requiring additional mobile technologies. Billinghurst [11] states that through AR that relies solely on the manipulation of the physical objects means "people with no computer background can still have a rich interactive experience".

While Augmented Reality may first appear like a natural progression within classroom environments, there are considerations that should be taken into account. Kerawalla *et. al.,* [17] outline a study involving AR within a formal primary classroom environment. They found that in their study, "children using AR were less engaged than those using traditional resources". In analysing their results, they developed a series of criteria that the authors recommend to consider when designing AR systems for the classroom:

- AR content must be flexible so that teachers can adapt it to the needs of individual children
- AR need to be as time efficient as existing methods of teaching
- The exploration performed with AR needs to be guided as to maximise learning
- AR within classroom environments needs to be designed for the institutional context

This study emphasises the importance of considering the type of activities in which Augmented Reality is used. Within this study, many of these considerations can become problematic due to the formal learning structure (such as the class presented with learning about planets). However there may be more potential in less-formal class activities, such as play-based learning, where the activities are by nature more exploratory and self-directed.

Play based learning includes activities where children are allowed to play with toys and other existing physical artefacts in a common space. These existing artefacts offer the potential of augmentation without running into the problems identified by Kerawalla *et. al.* [17]. Glos et al [18] discuss a study where toys were augmented with technology to encourage new forms of exploration, and found that augmented toys "are an effective tool for engaging children in technology and storytelling". Billinghurst et al [19] terms these artefacts "found objects - objects that have been produced for another use that can be re-purposed as an interface element". Beigl et al [20], reflect that this method of augmentation "will not be geared toward making them more computer-alike but at preserving their individual purposes and uses while enabling added value through digital information processing."

Alborzi et al [21] discuss the StoryRooms project, where children were encouraged to build their own objects within a custom designed interactive space. While such environments have major infrastructure considerations (as discussed earlier), there is promise in the idea of children being able to "develop their own story, by building props for the story using lowtech materials or any other object they may find in their surroundings".

Recently the concept of augmenting physical artefacts has been applied to childrens toys. Skylanders: Spyro's Adventures [22] is a hybrid computer game that combines a digital environment with physical toys to act as an avatar for the user. The user places a physical toy, which represents the in-game avatar, on the "Portal of power" (a NFC tag reader), which is connected to the game console. As the user progresses through the game, they are rewarded with experience, which is saved to that physical artefact. This artefact can then be taken to another users console, or multiple toys can be battled. The emphasis of the physical artefact being tied to the in-game experience allows the narrative that is presented in the digital world to be retold by the user during physical play. Similarly Appmates [26] digitally enables physical toys (in this case toy cars) with the ability for the toys to be used as an interface on a touch-screen tablet. As the toys are placed on top of a tablet, the tablet detects them and presents a race-track. As the toy is held, the screen changes to represent the car driving. Hornecker and Buur [23] present a framework for designing user experiences that focus on these kinds of tangible interaction, which augment environments. The authors suggest that the embodiment of tangible interaction "lend themselves to the support of face-to-face social interaction".

In a previous study [2], children interacted with tangible numbers and letters that triggered animations being played on a interactive table-top, The Discovery Table. The animations and sound were related to which letter or number the children played with. In this study, it was observed that the children started bringing paper and pens so they could trace the animals and characters from the animations on to paper. The authors found the children wanted to bring something tangible with them when they left the activity and the drawings were used when the teacher later had the children talking about what they had been doing during the day. Teachers showed a great enthusiasm to using Discovery Table in the classroom, however they also expressed insecurity and hesitation towards having to set up new technology they were unfamiliar with. Cuban [27] found that while teachers expressed a positive attitude to the usage of technologies for young students they seemed to only think of the technology as a supplemental activity.

Existing infrastructure in primary classrooms can be diverse across various schools. It is rare to find a one computer per student situation, and often there will only be one or two computers in a class of 25 students. Some schools have a robust internet infrastructure but many schools are still struggling with unreliable network access. Teachers can find it stressful having to troubleshoot technical issues when they have 25 primary students around them. *Save the wild* is a system designed with sensitivity to some of these issues. It can be used by several students at the same time, easily fitting within a classroom without requiring internet access, bespoke peripherals, or special equipment.

3. SAVE THE WILD

At The University of Queensland, a group of third year students designed and implemented the project *Save the wild* within an Interaction Design course. The objective of the project was to design and test a prototype that incorporates the theme of playfulness. *Save the wild* has been designed to suit the young primary school classroom with students between the ages of 5 and 8 years old. The project was designed to complement other ongoing classroom activities, where the children are working with a theme of sustainability. Specifically, the learning objectives that were in the study focused on learning about protecting nature by not throwing litter and rubbish on the ground.

3.1 Design

Save the wild is designed as a corner activity in a primary classroom. In this corner a small table and a few chairs (see Figure 1) are placed with an off the shelf computer on top of the table.

Figure 1 Table with the desktop computer set up for *Save the wild*.

Below the computer table a play mat is on the floor, the students can sit on the mat and fold up a variety of origami designs.

Students choose between eight animal figures (e.g. koala, fox, owl, frog), three rubbish figures (plastic bag, old paint brush and a glass bottle) or two recycling figures (recycling bin and recycling van). Each of the origami templates contains a fiducial marker (a marker technology which is a variant of a QR code), which is pre-printed onto the back of the folded paper (see Figure 2). Students construct the origami using instructions located with the collections of templates.

Figure 2 Children folding origami figures. The fiducial marker is pre-printed on the paper.

When a student has finished folding the origami figure, he or she can hold the origami up in front of the computer and there will be an animation appearing on the screen. The computer reads the fiducial marker with the built-in web-camera, and then displays the animation/narrative associated with the marker.

The system has a large variety of narratives to be displayed, both for single code scanning and for multiple markers simultaneously. This means that students can play with *Save the wild* individually but also together in groups of students, and see the on-screen narratives interacting with each other.

The focus of these narratives is to show how animals move and live in nature. When a student holds up the origami animal in front of the computer e.g. a snake, an animation will be played showing how the snake is moving around on the ground. When the student moves the origami animal away, the animal will disappear from the screen. When a rubbish origami fold is held up in front of the screen there is an animation representing the rubbish e.g. a glass bottle. If an origami of an animal is triggered the animal will now move on the screen but also get injured by the glass bottle that broke in the former animation. The rubbish can only be removed by one of the origami designs of a recycling bin or van. The recycling origami will initiate an animation of a recycling van moving over the screen and then the rubbish will disappear from it. This allows individualised stories to develop for each student as they show and hide origami, allowing for a playful and customised experience. The experience of a narrative, due to the physical nature of the origami, can be taken away by the student to reflect on later.

4. DATA AND METHODS

In order to understand how children interacted with *Save the wild*, and to evaluate the potential of the system to support regular classroom activities and convey ecological content, the prototype was independently deployed in two settings. Our methodological approach was naturalistic [25]; we gave priority to collecting observations of children's interaction with the system without our intervention or instruction. This better enabled us to appreciate how well (or not) the system communicated its possibilities for interaction to target users, what affordances it provided, and what expectations of their own young users brought to it. Below we present results from our two observational studies of children interacting with the system.

Figure 3 A girl trying to activate a narrative being played on the screen, the camera cannot read the code as it is facing the wrong direction.

4.1.1 At an exhibition

Save the wild was exhibited at a competition venue for school students in grades between 3 and 12, including a sizeable audience of younger siblings. The exhibit display was positioned at a central point in the venue where many visitors would pass by. For this venue, the system was presented on an off the shelf iMac that sat on a children's play table. The computer and play table were decorated with colourful greenery such as flowers, plants and vines. In front of the screen on the table were multi-coloured origami figures, templates and folding instructions. The first author stood nearby the installation, observing the children when they were playing with *Save the wild*, taking photos and writing notes to record the activities that occurred. A short survey was conducted with the participants after they had played with the system. In all, 51 children between the ages of 2 and 13 years played with *Save the wild*. In this group there were 38 girls and 13 boys; 33 were between the (target) ages of 5 and 9 years old.

We found that the children were very curious to the colourful setting we had created but they seemed not to initially understand what to do. Many of the children who came by the setting first tried to play on the computer but when they found nothing interesting happened on the screen, their attention moved to the table where templates and instructions to create origami were located. After engaging in folding origami figures, the children moved back to the computer and tried to use the artefacts to interact with the system. As the children were playing with the paper figures, the camera would pick up some of the printed markers and trigger an animation on the computer screen. The children who were around 5-6 years of age soon became curious about the code on each origami figure. Most of the children discovered that the computer recognised the figures when they held them up to the computer. We found that once the children had seen someone holding up the origami figure in front of the computer, many more children wanted to join and to see what happened when they held up their figure. At first the children did not see the connection with the printed code and the computer. They would just hold up the figure facing towards the computer (all codes were printed at the back of the figure) (see Figure 3).

Once the students had realised they needed to have the printed code towards the camera they became very aware of this and some overdid the positioning of the origami figure by putting it too close to the computer. Often parents or an adult pointed to where the camera was located. By watching other children most of the students realised that they did not need to put the origami figure close to the screen. It was only the youngest participants (2-3 year old) who struggled to understand how to position the figures.

Out of the 51 participants, the children from 8 years old and younger came back several times to play more with *Save the wild*. The younger students also tended to stay for longer periods compared to the older participants.

Certain aspects of the system were not self-discovered by some children. For instance, many of the younger children (2-7 years old) did not discover on their own how to clean up the rubbish that had collected on the screen. These younger children learned how to 'clean up' the environment by watching the older students interact with *Save the wild*. Once the younger ones had seen how the older students used the recycling origami figures, however, they had no problem copying the behaviour to remove the bottles and plastic bags from the scene. We found that this social learning allowed for a sense of understanding of the system as opposed to the difficulties encountered when adults attempted to explain the technology.

After only a short period of time of playing with the system, all the children were able to understand how to use *Save the wild* by scanning the fiducial markers. However, very few of the students realised that they could combine the origami figures to initiate more new activities on the screen. Many children tried to interact with the animals on the screen by touching and trying to make swipe gestures (see Figure 4) on the computer screen. A parent commented on how natural and intuitive it seems for the children to interact with the figures on the computer screen compared to how adults behave.

From our observations in the exhibition study, we found that the *Save the wild* experience provided an interesting way to augment the physical activity of Origami. Our observations of the social learning (where children observed others using the system) gave us insight into how features of the system can be discovered and taught to others, without explicit adult intervention. As our principal interest was in augmenting learning in a classroom environment, our second study deployed *Save the wild* within a classroom environment, to observe how primary school children explored the system in the course of a lesson.

Figure 4 A child trying to interact with *Save the wild* by touching the screen and making swiping gestures.

4.1.2 In a classroom

For the second user test we set up *Save the wild* as part in an Australian grade one classroom. The computer was set up in one of the corners of the classroom. The set up consisted of one computer screen, origami paper, instructions on how to fold various origami animals and objects and one small paper box consisting of already made up origami animals and objects. 22 children, 10 girls and 12 boys, aged 5 to 6 years old tested the system.

We sat on the floor close to where the children were playing with *Save the wild*. As the study progressed, we made observations using a mobile phone camera and taking notes. This second user study aimed to study how young students in a classroom interact with *Save the wild* without parental or adult instruction.

The teacher had given the students two tasks to work on for the day. The first task was to individually organizing their yearly portfolios and the second task was to do exercises from a Christmas workbook.

We intentionally did not introduce or explain *Save the wild* so that the children could freely play with the system, as they liked. The teacher had agreed to allow the students to play with *Save the wild* whenever they were interested.

Initially, the students stayed at their desks while working with the tasks their teacher had instructed with. A few students peered curiously at the corner. A few other students got excited when they recognized that there was an origami activity. After only a few minutes, two girls came and asked why there was a computer in the corner. They asked us "what is it?", and we responded "Why don't you go and have a look to see what it is. You're allowed to have a play." The two girls walked over and sat down in front of the computer. They discussed the pretty forest and then they picked up one origami animal each. The girls did not know how the two worked together but soon they played with the animals in front of the screen. Suddenly. One of the girls calls out, "Look, did you see something moving?" "How did that get there?" The other girl was quiet with a fascinated expression on her face. The first girls continued, "Do you think it was this (holding up her origami animal)?" The girl holds up her animal but nothing happens.

The girls continue playing with their animals and suddenly there's movement on the screen again. "Look!" The girl is pointing to the screen. "Lift up your animal again." The girls figure out that the origami folds are making things appear on the screen and they get very excited. The girls giggle and try different animal folds and they are fascinated about the screen appearances. After around 10 minutes of play the girls discover how the animals will disappear from the screen when the children stop playing with the origami animal but also how plastic bags and glass bottles will fall and break at the bottom of the screen. One of the girls discover how the recycling bin is swiping away some of the bottles left on the screen. She says, "Oh look, it swipes the bottles off the screen". The other girls says, "The animals get hurt, see they're bleeding". A third girl has joined the other two girls and she says, "It's fun smashing bottles." The second girl calls out, "Clean up!" The students tended to test out the "bad" origami folds but as the play continued they seemed to not want to make the animals injured and therefore avoided the plastic bags and glass bottles. One boy discovers how the objects are hurting the animals and calls out, "the birds are dying. Get the recycling bin because the birds are eating the plastic bags."

Almost all students have a short learning curve before they discover how the animations are triggered on the screen. When the animations are not happening, the students try to put the animal fold closer to the screen or they try to swipe or flick the animal quickly in front of the screen. When one of the students does not know how to make their origami animal appear on the screen, other students kindly offer their help and explain how to hold the marker towards the screen. One boy is keen to help other students hold up the origami animals so the computer screen will recognize the marker. When another student struggles to get his origami fold recognized, the boy points to the camera whole on the screen and says, "The sensor is up there". The student straight away tries to put the animal close to the camera and this does not work either so he picks up another animal. Only this one boy has difficulty making his animal appear on the screen. But he does not seem concerned about his animal's lack of appearance on the screen and he happily participates in the playing with the paper animals.

The children play together with *Save the wild*. On the occasions when two or more students are sitting and playing in front of the screen, the animations starts interacting with each other. "Oh, the snakes are kissing!" a boy cheerfully calls out. The other children look up and they all giggle. "Try the snail now", another boy says. The boys have discovered how the animals can interact with each other when several animals are held up together. "Oh, yeah!" (The children see a snake being carried away by one of the birds.)

After the children have finished playing with *Save the wild* they take their origami folds back to their desks. During the day we notice how many of the students continue playing with their origami folds and they make up little stories around their play. Two of the boys stop us and asks us to watch their new story. "Look miss, we have made a story about the unimaginable: a snake makes best friend with a fox."

5. DISCUSSION

There are a number of discussion points we have drawn out of our observations with *Save the wild*. While the case material we have presented does not warrant broad generalizations, there are several design relevant observations that have helped us build an understanding of how the system worked in these two contexts. Specifically, systems like *Save the wild* (a) support 'passive' augmentation (b) leverage everyday skills over digital literacy (c) allow for 'walk away' interaction and support the construction of user-generated narratives and (d) make small demands on existing infrastructure. They also may (e) create false or misleading expectations for interaction. Our discussion is organized around these observations.

Support passive augmentation. In both the Maths Trail and Discovery Table examples, the emphasis of the activity was tied to interacting with the digital on-screen environment. While the artefacts of interaction were physical, the activity relied on active engagement in a digital environment. In contrast, the activity and interaction for *Save the wild*'s origami activity is augmented by the digital environment, and the play (and learning to an extent) could take place within or outside of the digital scene. The physical origami figures are not only a means of manipulating digital information; instead the play with the physical artefacts is enhanced, but not dictated through, what has been digitally augmented. This is what we refer to as 'passive' (i.e. take-it-or-leave-it) augmentation; in an important respect, the digital experience is optional. Instead this is an example of education through experience and open-ended play, rather than through navigating information environments. *Save the wild* creates a digital experience by passively augmenting physical play. In this respect, fiducial markers were an excellent technology to support the embedded nature of this physical/digital interaction. Due to the passive nature of the markers they could be effortlessly attached to artefacts that carry pre-existing meanings and possibilities for interaction (other than as a means of interacting with the system).

Leverage everyday skills over digital literacy. The origami exercise in itself was half the success of *Save the wild*. Children sat down and folded their own characters and objects. By the time the origami figures were successfully used to trigger animations on the screen, the children already had something invested in those characters. The ordinary skills required to understand instructions, follow fold paper and recognize animal figures were the only prerequisites for play. Most of the children discovered the possibilities of the marker technology without needing a particular (right or wrong) concept of that technology or a theory of how the computer could recognize the figures. Through the study, it was found that children without prior experience in marker tracking learned the system quickly. Additionally, the technology was flexible in how close and in what position the physical artefacts could be held in relation to the screen.

Allow for 'walk away' interaction and support user-generated narratives. Two corollaries of the system's passive augmentation, inexpensive markers printed on origami paper, and the children's investment in creating their own figures were (a) that the system allowed for play away from and independent of the augmented habitat, and (b) that this supported user-generated narratives. In contrast to the design of the Discovery Table, for instance, *Save the wild's* focus on physical artefact construction allowed for 'walk away' interaction, where the learned experience at the installation lived on in the artifact away from the digital scene on the screen. This was observed in how the children continued playing with the figures throughout the day, and created their own stories after leaving the computer. While *Save the wild* inspired an ecological theme, it did not impose one on subsequent interactions, permitting a degree of playful latitude in the construction of new narratives around the origami figures.

Make small demands on existing infrastructure. We noted early in the paper that a central challenge in introducing technology to primary schools relates to the fact that the existing infrastructure in classrooms is just not dependable. While there are a number of systems that have been thoughtfully crafted for the learning goals of a primary education context, they often require more technology than one can be certain to find already in the classroom. Equally, teachers have different levels of confidence in, and competence with, involving new technologies in their curricula. In these respects, *Save the wild* made small(er) demands on existing infrastructure and technology, requiring only a desktop computer with a webcam, and no internet connectivity. Overall we are encouraged by the promise of Situated AR (where the technology belongs to the setting) for the possibilities it presents for leveraging existing infrastructure. Participating teachers felt comfortable with the technology as they only needed to start up the software and then they could leave the children to explore.

Create false expectations. On a more critical note, the technologies mashed up in *Save the wild* (webcam, fiducial markers, animations) created some expectations for system behavior that were not realized in the interaction. For example, we found that when children were explicitly guided on how the technology worked (being prompted by an adult "here is where the camera is"), they tended to incorrectly place the markers too close to, or directly on, the lens. However when students experimented unaided with the system, they were able to observe how and when the scene became interactive, progressively exploring the system. In general, explanations of the system in terms of its technology ("this is the camera" or "this is the marker") fueled false expectations that disrupted interaction [24]. We also noticed another tacit expectation emerge in interaction, to do with multiple artefacts being used to trigger animations at the same time. When they 'knew' how the system worked, the students tended to take turns holding markers to the screen. They rarely experimented with holding up multiple markers at the same time (a form of interaction the system actually supported). We feel that while fiducial markers (and other marker technologies) do support simultaneous markers, this was not behavior that was expected of the system. If we were talking about adult user behavior, we might be tempted to suggest that their expectations of system behavior were 'imported' from elsewhere, i.e. from the behavior of other forms of technology such as swipe card readers, RFID, ticket machines, mouse/keyboard, which typically only support a single input at a time. With respect to the junior age groups of users we are considering here, however, we are still looking for other explanations. However, false expectations were not always a detriment. The emergence of interactive difficulties also had a consequence of providing opportunities for peer learning. Students were able to learn from others how the system worked by observing and being shown how the figures created animations on the screen.

6. CONCLUSIONS AND FUTURE WORK

This study was to examine how existing playful activities could be augmented through the use of marker technologies. We found that the use of fiducial markers could extend this experience, without making heavy demands on the infrastructure already embedded within the classroom environment.

More studies of systems like *Save the wild* in real classroom settings are needed to determine the success of augmenting play to enhance learning, and the degree to which the discussion points we have identified carry over to other systems, other content and other classroom contexts. Careful attention to the existing infrastructure in classrooms can lead to the introduction of new technology that is not invasive but supports and enhances existing classroom and learning activities. Through the use of the markers, physical activities (such as the origami) can be extended and reused to help reinforce the learning objectives, passively augmented by technology. We are planning further studies in the area of seamless interaction through the use of tablets and augmented reality. We are continuing more studies in how walk-away interactions with technology can create more exciting collaborative experiences in the classroom. While we wait for the large-scale introduction of technologies into classrooms, we can leverage existing infrastructure to creatively augment learning environments in pedagogically meaningful ways.

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