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Design, Story-Telling, and Robots in Irish Primary Education

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Abstract

This paper describes "Empowering Minds," a collaboration between the MIT Media Laboratory, St. Patrick's College, and Irish primary school teachers. In this project, we are introducing LEGO Mindstorms technology into Irish primary schools, along with a framework for teacher professional development that centrally recognizes teachers' passions and interests in bringing about pedagogical change.

1 Introduction

LEGO Mindstorms is a robotic construction kit launched by the LEGO Group in 1998. The system is based on research conducted at the MIT Media Laboratory led by Seymour Papert. Early work included the Logo Brick, a small "programmable brick" used in activities with fourth- and fifth-grade children [1].

The MIT team continued to develop the concept throughout the 1990's. Work included technologies used in undergraduate engineering education and smaller programmable bricks called "Crickets" which have been used in scientific investigations with school children [2].

A late MIT prototype of the Mindstorms concept was used in an integrated, project-oriented fashion in the Peace Dale elementary school in Rhode Island [3]. The work described in this paper shares the cross-curricular approach used in these classrooms.

A related yet original approach to bringing this robotic technology to children is proposed by Bers and Urrea [4]. In this project, Mindstorms technology is used by children, parents, and teachers at a Jewish community center to explore spiritual values. Our work described here shares Bers and Urrea's focus on the narrative, story-telling ingredient of children's technology projects.

2 Framework and Goals

The work described in this paper was conducted in four Irish primary schools that are part of the "Empowering Minds" project, which was created in a collaboration between the MIT Media Laboratory and St. Patrick's College. The project is supported and funded by Ireland's National Centre for Technology in Education and *eircom*, the recently-privatized Irish telecommunications company, under a special grants program that specifically encouraged collaborations between Irish schools, universities, and industry.

The Empowering Minds project was founded with three core principles:

1. To encourage children and teachers to develop technological fluency by project-based learning to bring ideas of design, control, sensing, and programming to children.
2. To use technology as an integrating agent within the primary school, connecting these new ideas with the existing curricular content.
3. To establish a new model of teacher professional development, in which in-service teachers are centrally included in the design process of constructing new activities for their students.

This paper focuses on the first two of these goals—the ways in which a new technology (LEGO Mindstorms) can bring new ideas into the lives of children, and in the hands of creatively empowered teachers, let children explore concepts in the traditional curriculum in new ways. For more on the overall design of our project, and the role of teachers within it, please see [5].

The Empowering Minds project began in the spring of 1999, with a workshop conducted over the Easter holiday. Four schools with two classroom teachers each had been recruited by this time; we chose a representative selection of different types of schools in Ireland (urban-disadvantaged, suburban-advantaged, typical suburban, and rural) so that our ideas would be tested in different situations.

The teachers entering the project had no experience with the Mindstorms materials. In the first workshop, we immersed the teachers in the sort of design experience we hoped they would recreate for their students.

After this initial workshop, each classroom was provided with approximately USD$2500 worth of LEGO Mindstorms materials (described in detail in the following section). The teachers then introduced the materials to their classroom, in an exploratory and informal manner, at the end of the 1998–1999 academic year.

A second week-long workshop was held in August 1999. This was followed by full class work conducted in earnest by each of the teachers over the fall 1999 semester. In the spring of 2000, each of the teachers began extended, in-depth project work, the result of which is the subject of this paper.

3 Materials

The LEGO Mindstorms kit is packaged in several fashions (somewhat differently for the retail market and the scholastic market), but in all configurations, it consists of the following:

- The "RCX Brick," a programmable LEGO brick that contains a tiny computer, batteries, a display screen, and circuitry to operate motors and connect to sensors
- Motors and various sensors, including touch sensors and light sensors
- A large collection of LEGO building blocks, including the traditional bricks, decorative pieces, and newer pieces like gears, beams, axles, and other mechanical components

The Mindstorms system is provided with either of two different software environments: *RCX Code*, which ships with the retail toy-store version, and *Robo-Lab*, which ships with the school versions. We and the teachers in our project found the Robo-Lab interface unnecessarily complicated, and the teachers chose to use the RCX Code software. (Other programming environments developed by Mindstorms enthusiasts are available, but these are suitable for programmers rather than being designed for children.)

Figure 1 shows the RCX Code programming environment. A program is constructed by snapping together puzzle-piece-shaped screen icons, each of which contains a single command. Special "sensor watcher" blocks act like daemons, continually testing a sensor condition and executing the stack of blocks connected underneath when the sensor condition becomes true. This multi-tasking capability makes constructing certain behaviors much simpler, but can also be confusing to children.

Figure 1: RCX Code Programming Environment

4 Project Descriptions

In this section, three extended projects carried out by the teachers and children involved in the research are presented. These projects are an illustrative sample of the work done across the eight classrooms and four schools. Because of space considerations in this paper, we present work from only three of the eight classrooms in the project.

These projects will show both how children learn technological concepts embedded in the context of project work, and how traditional curricular content is learned through creative expression. In each project, we describe the narrative that is used to scaffold the children's work, and point toward the technical and pedagogical issues raised by these activities.

4.1 Táin Bó Cuailnge

Táin Bó Cuailnge—meaning, the Battle of the Bulls—is an epic story in Irish lore. A project around the legend was guided by Tommy Maher, a teacher in the Clontubrid National School. Clontubrid is a two-teacher public school located in the parish of Lisdowney, near the town of Kilkenny. (Because of many factors, including its rural nature and its local orientation, Ireland has a heritage and continuing support for small, one-, two-, and three-teacher primary schools, located in rural areas.) Mr. Maher's class consists of a mixed age group of sixteen children, including the third through sixth classes (children nine to twelve years old).

In the Táin Bó Cuailnge legend, Medb, an ancient queen of a western province of Ireland, needs to procure a powerful bull to equal the majesty of a bull owned by her husband Ailill. She learns of a worthy bull, the Brown Bull of Cooley, and goes to war with its owner to win it.

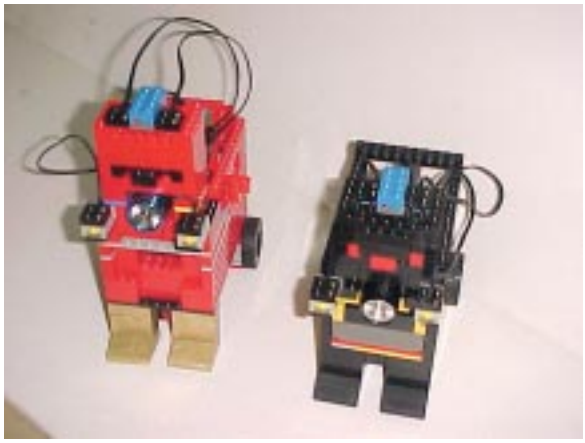

Figure 2: The Bulls of the Táin

The final part of the tale recounts the fight of the two bulls when they meet. The Brown Bull of Cooley killed the king's White-Horned Bull, impaled his body on his horns, ran around the whole country scattering parts of the bull in different places around the country, and finally collapsed and died himself. The places where the parts of the White-Horned Bull landed gave their names to that place; e.g., the Irish name for Dublin is Baile Átha Cliath (the town at the ford of the ribs).

In the hands of a teacher like Mr. Maher, students learn that myths like this one often have a basis in fact. In this case, as Mr. Maher explains:

> The story seems to have some loose basis in fact and to stem from folk memories of ancient actual wars between the northern and southern parts of Ireland. As cattle were, in ancient Ireland, regarded as units of currency, units in which all debts and fines could be paid. Even a murder could be forgiven by the payment of a certain number of cattle and each class of person in society had an honour price measured in cattle.

The children chose the Battle of the Bulls as the part of the Táin to illustrate, having examined each of the seven parts of the story. In the previous year, some of the children made PowerPoint presentations of the entire tale; in their work with the Mindstorms materials, these stories were brought to life.

The children decided to build bulls from the Mindstorms materials, and initially had both bulls trying to find each other by sensing and following light. The light source was a small high powered flashlight mounted in each of the bull's heads (see Figure 2). After a lot of time and effort spent programming and testing, however, this strategy had to be abandoned as the light source was too easily corrupted (e.g., by turning on an overhead lamp or the main classroom lighting).

Another complication was that a bull would sometimes reverse too far out of range and consequently no light source could be detected by the other bull. This problem of light sources causing difficulties was a recurrent theme which the children in all classrooms involved in the project experienced at one time or another, causing them to rethink how they were going to solve the problems they encountered.

The children went about redesigning the bulls to simulate the battle. Inspiration came from another group of children in the class who had been working on building a bug which reversed when its antennae hit an object. Using this concept they built a set of horns for each of the bulls which when struck would release a touch sensor. This would cause the bull to retreat before driving forward to attack again. When building each of the bulls great care had to be taken to ensure that both sets of horns were at the same level to facilitate the releasing of the touch sensors.

The children also decided that the victorious bull would do a victory charge around the large map of Ireland to symbolize his trip around the country. They made a large map of Ireland with holes at the places named from the bull's body parts. These place names had covered LEGO lights behind, which were all wired back to an RCX. As the bulls fought they were programmed to send occasional signals back to the RCX running the lights. When this RCX received the signal it was programmed to have the lights on the map flashing on and off.

Much of the technical challenge in this project revolved around the interaction between the two bulls and the map. The children made good use of the RCX's built-in communications capability, both in the bulls' interactions, and the subsequent map display. In essence, the children designed a system that consisted of three separate yet interdependent entities, and programmed them so that a desired pattern of interaction would occur.

4.2 Castletown House

The Castletown House project was led by Joan O'Rahilly, a teacher at St. Finian's National School, who had a fourth class (children aged 10 years old). St. Finian's is a medium-sized public school (approximately 220 children) located in New Castle, a suburb of Dublin.

Ms. O'Rahilly's class drew inspiration from the local legend of Castletown House, a large mansion in the nearby town of Celbridge. In the Castletown House story, hundreds of years ago the owner of the manor spent a day hunting, and while on the hunt met a handsome stranger, whom he

Figure 3: The Castletown House Model

befriended and invited back to his home. That evening, while playing cards with the stranger, the owner happened to drop a card off the table and when picking it up, noticed that his companion had cloved hooves as feet. Panic and other excitement ensued as he realized he had invited the devil into his home! A priest was sent for to exorcise the devil. The priest threw a bible, which shattered a mirror, and chased the devil into the fireplace. The devil then escaped as a puff of smoke through the chimney.

When the class decided upon the Castletown House legend as a project theme, Ms. O'Rahilly organized a series of activities to engage the imaginations of the children, and integrate this work into the life of the classroom. The class took a field trip to visit the mansion itself. While there, children took photographs of the house with the digital camera that was provided to the school as part of the project.

Back in the classroom, the children engaged in many activities to interpret the Castletown legend. They had extensive discussions, dramatic role play, storyboarding and other drawing, as well as writing up their own stories. It was the basis of classroom work for a good period of time, explored at many levels. With art materials, the children re-created features of the house, including the furnishings and portraits (Figure 3).

As the central project, the class designed a miniature Castletown House of their own, which they populated with characters from the story—LEGO models controlled by the RCX bricks running programs written by the children. These actors included the lord of the manor, the devil, the priest, a maid. Figure 4 shows a child working on the devil.

The house itself also incorporated active elements, including window frames that moved up and down on their own, and flashing lights to suggest fire in the fireplace.

The children conceived of a complex series of events to be

Figure 4: The Devil of Castletown House

enacted by the models representing the characters of the story. When they made their initial plan, they imagined each of their actors would work perfectly and predictably, but the reality was far from their ideal vision. Much of the children's learning resulted from facing the difficulties in implementing their vision.

For example, "The Maid" would start the story by moving towards the "Corpse in the Coffin." The Corpse's RCX would be waiting for a message which would signal it to rise out of the coffin and fall back down again. A pause was built into the Maid's program which would allow for this. She would then reverse as if in fright and begin a series of beeps to signal her alarm.

Then, the Corpse's RCX would in turn send a signal to the RCX controlling the windows, which would cause them to begin moving rapidly up and down to add suspense and terror to the scene.

However, this could not be done as the positioning of the RCX's infrared communications port did not allow it. If the Corpse's RCX port were aimed at the Maid, then it could not also communicate with the Window's RCX brick.

As an interim measure, the children incorporated a timed wait into the program for the windows. Later, they resorted to manually pressing the run button to control the windows, as they were not satisfied otherwise that the windows opened and shut at the appropriate time.

The central character was the devil and he presented a myriad of problems for the children. They wanted him to come into the room, stop and play cards. He was then to throw off his cape revealing who he was and when the priest

arrived he was to disappear up the chimney. The children wanted to program this sequence of events with a series of timed waits, moving the devil into his required locations by using a light sensor to follow a black line.

The biggest problem was getting the Devil to follow a black line. When the children solved this, and had learned how to reset the readings for different lighting conditions, they thought they had just to program the timed waits. But once the devil was programmed to respond to the line, it always did so, even when the children wanted it to move differently. The RCX Code did not provide a way to disable and re-enable its sensor-watchers.

Collectively, this project proved quite difficult to accomplish in the manner in which it was framed. Because each character in the story relied on others to work properly, children could not choose one piece of the project and just get it to work individually; all of the actors in the story were interdependent with the others.

In subsequent work, Ms. O'Rahilly plans to guide her students toward a design with less tightly coupled sub-projects, so the small teams of children working on each piece can more readily integrate their results at the end.

4.3 The Selfish Giant

The Selfish Giant project was led by Ruth Kirwan of the City Quay National School. She had a combined second and third class (children aged 8 and 9 years old). City Quay is a public school located in the city of Dublin, and serves primarily children from economically disadvantaged backgrounds.

In Ms. Kirwan's class, the children used Oscar Wilde's story *The Selfish Giant* for inspiration. In the story, a giant owns a beautiful garden that is visited by children while the giant is away from home. When he returns, the giant evicts the children and builds a wall around the garden. From then on, it is always winter in the garden and spring never comes.

One day, the giant hears a band of musicians in his garden, but it is a single bird resting in a tree and singing a song. The bird had followed a little boy who had crawled into the garden through a crack in the wall. The giant finds the boy and lifts him into the tree, which suddenly bursts into blossom. The giant then realizes it's been forever winter in his garden because of his selfishness. He then opens his garden to the neighborhood children, and the normal cycle of seasons returns. The giant has a long and happy life, but he always misses the little boy.

One winter, the giant sees a flower in bloom and wonders how this could be. He then finds the little boy, and sees that he has the wounds of crucifixion on his hands. The giant is very upset, but the boy tells the him they are wounds of love, and invites the giant to join him in his garden in paradise. Later, the children come to play, and find the giant lying in his garden, covered with blossoms. They think he is sleeping, but soon realize he has passed away.

Figure 5: City Quay School's *Selfish Giant* Project

The story is especially meaningful to the City Quay children because Oscar Wilde as a child lived in the same neighborhood as the children do now, and his statue resides in the Merrion Square park which could have been the garden in the story.

Ms. Kirwan used this story as the hub for a variety of activities in her classroom. The children visited Merrion Square and saw Wilde's statue. They read the story aloud in class. The children wrote poems and short stories of their own based on the tale. And the class created a community project using the LEGO Mindstorms materials around the story.

In the class project, four 4 ft. square pieces of pressboard were arranged in a square. On this tableau, the children re-created the central scene and characters from the story: a large garden walled off from the rest of the city, a tree in the garden, the giant, and the boy. Figure 5 shows the completed project.

The children also represented elements from their own lives in the diarama. Outside of the walls of the garden, they included the town dump, a highway filled with automobiles, and gray factory buildings. Little security cameras were interspersed throughout. A large sign on the walls protecting the garden read, "Trespassers will be prosecuted."

The children used the RCX brick to program patterns of movement and beep sequences into several of the cars outside the garden walls (the rest could simply be pushed along manually). The giant was the biggest single LEGO construction, and it included an RCX brick programmed to make its eyes flash and its arms rotated back and forth. The children also built swings and merry-go-rounds in the playground which were activated by an RCX.

None of the children had LEGO experience coming into

the school year. These were among the youngest students involved in our project. And yet, they mastered fundamental building skills, like interlocking blocks to make a strong wall, making vehicles which could steer, and they learned basic programming and control concepts.

Most importantly, the narrative project framework gave all of the children a means for self-expression. In the final result, the children collectively built a model that not only interpreted Oscar Wilde's story but also demonstrated their own personal experiences of life.

5 Summary and Conclusions

This paper has described a framework for introducing LEGO Mindstorms materials into the primary school. Through three project stories, we have presented results from one school year's work, detailing activities in three of the eight classrooms in which the project has been running.

Through these examples, we can clearly see the ability of children to conceive and implement sophisticated designs. The children in the classrooms have been given both a technologically expressive set of materials along with the guidance of committed and capable teachers. The children conceived and implemented projects that incorporated crafts, mechanics, sensing, control and programming.

The teachers in the project supported the children's work in several ways. They provided a narrative context for the children's work. But also, they underwent a learning process themselves. As the teachers struggled with the Mindstorms materials, they became learners alongside of their students.

As such, the relationships amongst students and teachers changed. Children were in charge of their own learning. One of our teachers commented that deep down, he had the belief that this sort of constructivist learning was possible, and in this project he had seen it brought to life in his classroom.

As researchers, we have placed teachers' creativity into a central role in this project. Rather than prescribe activities to be carried out by the teachers in this work, we have asked each teacher to contribute his or her own expertise and passions in designing activities for their classroom.

As we carry the Empowering Minds project forward, we will continue to respect and encourage teachers' talents and creativity. We plan for the project to grow as the first round of teachers whose work is described here act as mentors to new teachers brought on board. Through this bottom-up process of growth and development, we hope to foster a new way of thinking about the role of technology in our classrooms of tomorrow.

Acknowledgments

We would like to thank all of the teachers who committed themselves to this project. They went far beyond the normal call of duty to accomplish great learning in their classrooms. In addition to the teachers whose work we have described here, our team included Clifford Brown, Terry Duffy, and Barbara McDonagh from St. Bridgit's National School in Castleknock, and Patrick Bunce, Mary Coyne, Mary Maher, and Brian Murphy.

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