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CHAPTER 6

ENGINEERS AND STORYTELLERS

Using Robotic Manipulatives to Develop Technological Fluency in Early Childhood

Marina U. Bers

INTRODUCTION

Young children can be wonderful engineers and gifted storytellers. As caring adults, our role is to provide them with early experiences to enable them to flourish as both. We want children to discover the ways in which the man-made world comes to be, the design process involved in each tangible or digital object in our houses and neighborhood, as well as the underlying powerful mathematical ideas that enable engineers to design and build sturdy structures and complex machines. We want children to realize that physics is part of our everyday experience and that the scientific method is a useful tool not only for conducting experiments in a white coat lab, but also for testing our very own theories about the world.

But we also want children to fall in love with language. We want them to tell and listen to stories, to experience the pleasure of both written and oral texts and to understand the structural, grammatical and linguistic choices

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that are made every time one engages in the art of storytelling. We want them to understand that letters, words and sentences have meanings, as well as authors, audiences and contexts, and we also want them to become aware of different narrative genres and the power of the written world.

Storytelling and engineering are two ways of understanding, making sense of and contributing to the world around us (Brunner, 1986). In the spirit of Piagetian theory, young children are both little storytellers and little engineers. Early childhood educators have long recognized this. In most settings we can find books as well as building blocks. However, as children grow and move forward in their formal schooling, we soon start to see a division of labor. Some children, who in kindergarten had pleasure in building and counting with their fingers, begin to shy away from math and science. For example, even though many girls may academically outperform their male peers in math and science courses, girls often lose interest or confidence in their abilities to do mathematics and science in middle school (Campbell et al., 2002; Eccles, 1997). There are many reasons for this, and describing all of those is beyond the scope of this work. This paper suggests that one of the reasons of this separation between the "I am good/enjoy math and science" vs. "I am good/enjoy language" is that children cannot find a connection between those very first enjoyable concrete experiences they had in early childhood and the abstract activities of the mind that they encounter in later schooling.

The issue of abstract and concrete is not new in education and became prevalent with Piaget's view of children's intellectual growth as proceeding from the concrete operations stage to the more advanced stage of formal operations (Piaget, 1952). Furthermore, the emergence of the computer incited researchers, such as Sherry Turkle and Seymour Papert, to call for a "revaluation of the concrete" in both epistemology and education. In their breakthrough article in 1991, they identified how

> The computer stands betwixt and between the world of formal systems and physical things; it has the ability to make the abstract concrete. In the simplest case, an object moving on a computer screen might be defined by the most formal of rules and so be like a construct in pure mathematics; but at the same time it is visible, almost tangible, and allows a sense of direct manipulation that only the encultured mathematician can feel in traditional formal systems. (Turkle & Papert, 1991)

While Turkle and Papert were describing the manipulation of virtual objects in the screen, the same process happens, and becomes even more powerful, when children are provided with objects that are physically tangible as well as digitally manipulable, such as robotic manipulatives. This paper proposes that robotic manipulatives can promote learning by both little storytellers and little engineers. Furthermore, the physical characteristics of these "concrete" objects foster the development of sensorimotor skills that, in early childhood, are as important as intellectual ability.

However, using a concrete object to learn important ideas about language, mathematics, physics, etc., does not guarantee that ideas from these domains will become concrete for the child (Clements, 1999). Wilensky proposes that *"concreteness is not a property of an object but rather a property of a person's relationship to an object"* (Wilensky, 1990). Therefore, *"concepts that were hopelessly abstract at one time can become concrete for us if we get into the 'right relationship' with them."* According to Wilensky, the more relationships we can establish with an object, the more concrete it will become, since

> concreteness, then, is that property which measures the degree of our relatedness to the object, (the richness of our representations, interactions, connections with the object), how close we are to it, or, if you will, the quality of our relationship with the object.

This chapter suggests that robotic manipulatives can help children make personal relationships with ideas through the use of sophisticated objects that introduce them to complex concepts in a concrete way. For example, the gears and motors of robotic manipulatives can invite children to think about powerful ideas such as ratios. Although this concept might be new in early childhood, the use of a manipulative object for promoting learning is not.

Robotic manipulatives engage children in building and programming personally meaningful objects, while providing an open-ended environment that fosters "epistemological pluralism" diversity in ways of knowing and approaching problems and ideas (Turkle & Papert, 1991). Although traditionally conceived as purely mechanical kits, robotic manipulatives can be inviting to both little engineers and little storytellers if presented with the right educational philosophy and pedagogy. For example, while some children might make robotic creatures and enact a play, others might focus on building cars or lifting bridges. Robotic manipulatives allow children to follow their own interests, in storytelling or engineering, wile providing objects that invite them to form, very early on, personal relationships with ideas. These ideas will be encountered later on, as schooling progresses, in a more abstract form.

While concrete objects (i.e., robotic manipulatives) are important to help children establish early personal relationships with abstract ideas, people are as important. The adults in the lives of young children, parents and early childhood teachers are, knowingly or unknowingly, helping them to make personal relationships with knowledge. As soon as they are borne, or even before, children are immersed in a learning environment (both home and daycare or school) in which adults and objects help them to make sense of the abstractions of language and to form a special relationship with the spoken word. This early relationship is fundamental for later literacy.

Many adults already have deep relationships with language and find intuitive ways to help young children develop their own by encouraging them to talk, to sing, to play with rhymes, and as they grow, to recognize the letters of their name and read everything from cereal boxes to the newspaper. And for those adults who do not have the intuition or an already established relationship with written language, many early literacy programs and interventions provide them, with diverse degrees of success, with some of these tools and strategies (Goodling Institute for Research on Family Literacy, 2006; National Literacy Trust, 2001).

However, the situation is very different for mathematics, science and technology. Most adults did not form relationships with these areas of knowledge when they were young. Thus, it becomes harder for them to engage children in early explorations of numbers and data. As children grow and the complexities of the disciplines increase, it becomes even more difficult for adults to support children's learning and for children themselves to establish personal connections. This is amplified by the fact that mathematical and scientific awareness are not as embedded in our culture as literacy is. When the computers began to enter everyday lives, visionary educators realized that this new object could be fundamental in changing this. As educational software was developed, research showed that computers enabled children to make concrete connections with mathematical ideas by providing a rich and accessible object (Papert, 1996).

Robotic manipulatives extend the possibilities of the computer by providing an opportunity to relate to concrete objects and ideas, while respecting the plurality of ways of knowing of little engineers and little storytellers. In this paper, I suggest that the little storytellers and the little engineers can learn to form closer relationships with abstract mathematical and scientific concepts by engaging in the design of their own personally meaningful robotic projects. And at the same time, they can learn to develop technological fluency, a set of skills and attitudes that are increasingly needed in today's society.

ON THE SHOULDER OF GIANTS: FROM BUILDING BLOCKS TO ROBOTIC MANIPULATIVES

Robotics can be a powerful learning manipulative for young children. It can enable the early introduction of engineering and programming skills, as well as the understanding of abstract mathematical and science concepts in a concrete, playful and hands-on way. Since Froebel established the first

kindergarten in 1837, and developed a set of toys (which became known as "Froebel's gifts") with the explicit goal of helping young children in learning concepts such as number, size, shape, and color, other educators, such as Maria Montessori, have created a wide range of manipulative materials that engage children in learning through playful explorations (Brosterman, 1997).

Nowadays, the use of manipulatives as a teaching tool is widespread. Most early childhood settings have building bricks, Pattern Blocks, Digi-Blocks, Cuisenaire Rods, etc. These manipulatives, not only can be used as teaching aids, but also as materials for fostering creativity. They enable students to build, to design, to experiment and to solve problems. "Digital manipulatives" are now supplementing these traditional manipulatives, because they also afford students the opportunity to explore ideas and concepts beyond what traditional manipulatives can provide, for example dynamic concepts such as feedback (Resnick, 1998). Robotic manipulatives, such as the ones this paper focuses on, extend the potential of digital manipulatives by enabling children to use their hands and develop fine motor skills, as well as hand-eye coordination. But even more important, they provide a concrete and tangible way to understand abstract ideas.

Robotic manipulatives engage children in the design of their own projects. Children can explore traditionally abstract concepts such as gears, levers, joints, motors, sensors, programming loops and variables in a concrete and fun manner, while engaging early on in most of the steps involved in the engineering design process (Erwin et al., 2000). This way of working with robotics in early childhood is strongly inspired by the constructionist philosophy of education, which conceives technology as a playful material to make personally and epistemologically meaningful projects (Papert, 1980).

Constructionism asserts that computers are powerful educational technologies when used as tools for supporting the design, the construction, and the programming of projects people truly care about (Papert, 1980; Renick et al., 1996). By constructing an external object to reflect upon, people also construct internal knowledge. Constructionism has its roots on Piaget's constructivism (Papert, 1991). However, while Piaget's theory was developed to explain how knowledge is constructed in our heads, Papert pays particular attention to the role of constructions in the world (i.e., robotic constructions in this case) as a support for those in the head. Thus, constructionism is both a theory of learning and a strategy for education that offers the framework for developing a technology-rich design-based learning environment, in which learning happens best when learners are engaged in learning by making, creating, programming, discovering and designing their own "objects to think with" in a playful manner.

Robotic manipulatives are powerful "objects to think with," when used in the context of a constructionist learning environment that gives the individuals the freedom to explore their natural interests using new technologies, with the support of a community of learners that can facilitate deeper understanding.

In the work described in this paper the robotic manipulative used is a commercially available robotics kit, called Lego Mindstorms Robotic Invention Kit. The kit contains a large Lego brick with an embedded microcomputer, called the RCX brick, an infrared USB tower that connects the RCX to the computer, so the programs that children create in the computer can be downloaded to the RCX, and a variety of Lego pieces in different sizes and shapes. Some of the pieces are familiar, such as beams, bricks, and plates. Others are unique to robotics such as motors, light sensors, touch sensors, wires, axles, and gears. The RCX has three input connections (for the touch and light sensors) and three output connections (for motors and lights). In addition, an LCD display provides information about the input and output connections as well as data stored in the processor (see Figure 6.1).

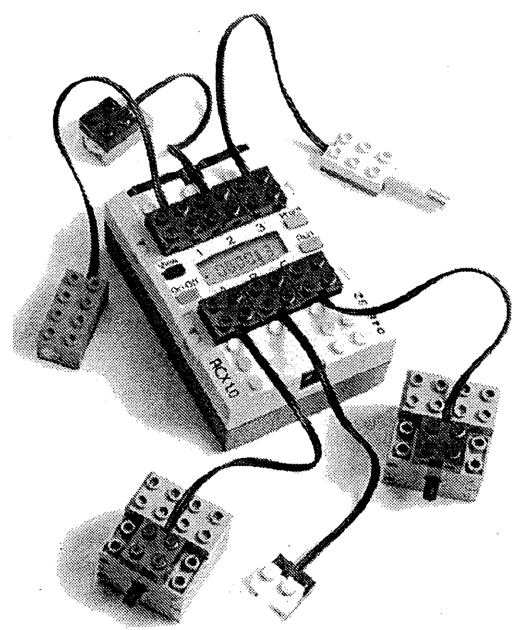

Figure 6.1. The RCX with sensors, motors and a light connected to inputs and outputs.

Figure 6.2. A simple program in ROBOLAB built with two motors, A and B, that go forward for 4 seconds, then go backwards for 2 seconds, then stop.

Children can include the RCX in the building of their project. Since it does not need to be connected to the computer (the program can be downloaded through the tower), children have flexibility in the type of creations they can make, as well as in deciding the behaviors of their projects. They can create a moving car that follows the light or a merry-go-round that plays their favorite tunes. In order to program behaviors for their robotic creations, such as motion and reactions to stimuli (i.e., if there is light, then go forward; if the touch sensor is pressed, then play a sound), children can use ROBOLAB™, a software program developed at the Tufts University Center for Engineering Educational Outreach (CEEO), one of several educational software packages available (see Figure 6.2). ROBOLAB is a programming language that provides a drag-and-drop iconic interface that has several levels of difficulty, so the user can tailor the functions that are available to their personal programming skills (Portsmore, 1999).

TECHNOLOGICAL FLUENCY: BEYOND TECHNOLOGICAL LITERACY

To make their robotic creations come alive, children manipulate the physical Lego pieces to build sturdy and efficient structures, and program the software to make the robotic project behave in the way they want. Building and programming engage children in learning about physics, math and engineering concepts. It also encourages them to start wondering about our surrounding world, which is populated by objects that, in the same spirit as robotic manipulatives, integrate bit and atoms (Gershenfeld, 2000). Most important, robotic manipulatives provide an opportunity for children to develop technological fluency very early on.

Papert has coined the term technological fluency to refer to the ability to use and apply technology in a fluent way, effortlessly and smoothly, as one does with language. For example, a technologically fluent person can use technology to write a story, make a drawing, model a complex simulation or program a robotic creature (Papert & Resnick, 1993). As with learning a second language, fluency takes time to achieve and requires hard work and motivation. In order to achieve technological fluency, it is imperative to develop technological literacy, or basic skills.

To express ourselves through a poem, we first need to learn the alphabet. In the same spirit, to create a digital picture or program a robot, we first need to learn how to use the keyboard and to navigate the interface. Technological literacy has sometimes come to be known as "computer literacy" and has a long history. It refers to the ability to use computer applications, such as a spreadsheet and a word processor, and to search the World Wide Web for information. However, skills with specific applications are necessary but not sufficient for individuals to prosper in the information age, where new skills are constantly needed because applications change rapidly and new tools emerge frequently, requiring new skills.

While learning the alphabet is required to write a poem, it is not enough. In the same spirit, knowing how to use some software packages is not enough to become technologically fluent. As stated by the Committee on Information Technology Literacy in 1999, *"the 'skills' approach lacks 'staying power'."* In this paper I am suggesting that technological literacy is a fundamental stepping stone toward technological fluency, but not a goal in and by itself. I am also proposing that, regardless of the age of the children and the challenge to create developmentally appropriate curriculum and software, the goal should be to promote technological fluency and not merely technological literacy.

Technological fluency is knowledge about what technology is, how it works, what purposes it can serve, and how it can be used efficiently and effectively to achieve specific personal and societal goals. The Committee identified at least four broad categories of rationale motivating the need of helping children develop an understanding of information technology: personal, workforce, educational, and societal (Committee on Information Technology Literacy, 1999).

Thirty states include technology education in their educational frameworks (Newberry, 2001). Massachusetts is leading the nation in declaring that technology and engineering are as important to the curriculum as science, social studies, and other key subjects. The Massachusetts Science and Technology/Engineering Curriculum Framework (Massachusetts Department of Education, 2001) mandates the teaching of technology and engineering for all students in grades PreK–12.

Robotic manipulatives provide a venue by which to engage children in developing technological fluency (Miaoulis, 2001; National Academy of Engineering & National Research Council, 2002; Roth, 1998; Sadler et al., 2000). They also offer a platform for project-based learning (Resnick et al., 2000) that promotes design processes such as iteration and testing of alternatives in problem solving, encompasses hands-on construction that can promote three dimensional thinking and visualization, offers design-based activities to engage students in learning by applying concepts, skills and strategies to solve real-world problems that are relevant, epistemologically

and personally meaningful (Papert, 1980; Resnick et al., 1998). Robotic manipulatives also provide a wonderful opportunity to integrate different areas of the curriculum, such as math and science with the humanities and the social sciences (Benenson, 2001). Last but not least, robotic manipulatives can motivate students to engage in learning complex concepts, in particular in the areas of math and science, even when they label themselves as "not good at" or "not interested in" this (Bers & Urrea, 2000).

Although many high schools and middle schools have adopted some form of engineering education through robotics (Bayles & Aguirre, 1992; Jaramillo, 1992; Kreinberg, 1983; Metz, 1991), very few elementary schools actively do so (Benenson, 2001; Rogers & Portsmore, 2004) and a handful of early childhood settings are exploring the use of robotics in early childhood (Bers et al., 2002; Bers et al., 2004, Bers, 2004; Beals & Bers, 2006).

Robotic manipulatives provide opportunities for both little engineers and little storytellers to develop technological fluency, while respecting and engaging their epistemological styles and ways of knowing the world (Bruner, 1986). In the next section I present examples of this.

LITTLE ENGINEERS AND LITTLE STORYTELLERS

Robotic manipulatives can engage children in developing technological fluency. However, regardless of the tool, the best learning experiences happen when children are deeply invested in their own learning. Thus, as mentioned earlier, the pedagogy is as important as the technology. Within the constructionist approach, it is essential that children have the freedom to make projects they truly care about. Over years of conducting research and teaching children to use robotics, I have observed that some children tend to choose projects that reflect early engineering tendencies, while others tend to choose projects that engage their storytelling potential. Robotic manipulatives allow both types of children to create meaningful projects, and at the same time, to develop technological fluency while exploring both the physical and the digital worlds.

Max used robotic manipulatives in a combined first and second grade classroom in a small private school in MA. When given the choice to build a project he decided to make a "hoping Eskimo." In his journal, he wrote *"My Eskimo hops and runs away from a polar bear. I built this because I am an Eskimo."* Max wanted to use the technology to tell a story, a story about himself and his cultural heritage (see Figure 6.3). The open-ended nature of the technology enabled Max to work on this project. But it wasn't only the technology that made this possible. It was also the constructionist pedagogy that Max's teacher used when introducing robotics.

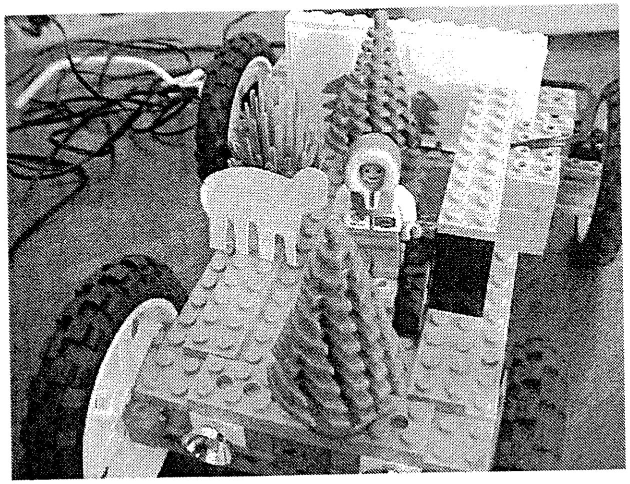

Figure 6.3. Max's hoping Eskimo.

Max was not as interested in exploring the potential of the technology as an end in itself, as many of the children that I classify as "little engineers" were, but he wanted to tell a story. When Max recounts his work on the project, this priority is also expressed by the order of the steps he describes. "*First I built a platform. Then I built the background. Then I built the Eskimo and the trees and then the motor for the Eskimo. I put a lot of slow motion into the motor of the Eskimo. And then I put a lot of fast speed into the wheels. I learned that is mostly very hard to support the car.*" The last thing Max did was working with the motor and program its speed. He first needed to have the setting for the story (the platform, the background and the trees), and the main character (the Eskimo). Then he could focus on the motor. As I will later describe, this approach differs from the one taken by children in the group which I classify as "little engineers." These children tend to first explore and make use of most of the fancy toys and pieces such as wheels, gears, motors and sensors.

Max used a motor and learned a few things about motion and programming. He had fun and he expressed that he enjoyed most "*to learn how to make things jump.*" However, using motors wasn't what got Max hooked into his project. He had a story to tell. He put the engineering skills and his evolving technical fluency to the service of storytelling.

I started with Max's story because Max is a boy and, his choice of storytelling, instead of engineering, is counter intuitive with traditional views that see boys as little engineers and girls as little storytellers. Girls and boys approach problem solving differently; for example, boys seem to be better

at tasks involving spatial relations, while girls seem to be better at verbal problems (Helgeson, 1992). However, some work started to explore what happens when the task is open-ended, such as the constructionist philosophy proposes, and children can choose a personally meaningful project to work that is holistic and relevant to real-world situations (Margolis & Fisher, 2002).

Very little education research has looked at how very young children use robotic manipulatives for learning. However, since research shows that attitudes about science and math start to form during the early elementary school years, it is expected that the same is true for engineering education. However, there is no research in this area yet. Elementary school girls are less confident in their math abilities than boys (Eccles, 1997), and both girls and boys perceive that science is male dominated as early as second grade (Andre et al., 1997).

While research has shown that there is a gender gap in technological fluency and a lack of women in engineering or technologically challenging professions (Thom, 2001), this paper hopes to suggest that the early use of robotic manipulatives can serve to bridge the gap between gender stereotypes and engage both girls and boys in developing technological fluency, while respecting their own epistemological styles and their interest in both building sturdy structures and telling stories.

Caroline, a classmate of Max, is also interested in stories. She was fascinated by the Nutcracker, not only because of the popularity of the ballet, but also because, in her own words, "*the Nutcracker represents Christmas.*" Caroline celebrates and truly enjoys Christmas. She chose to make a Nutcracker out of Legos for her final project. The doll opens and closes its mouth and its eyes light up. In her on-line design journal, with the help of a teacher, Caroline wrote: "*Some important parts of the building were getting the mouth attached to the head. The gears made the mouth go up and down. We had to put it on the platform or it would be tilted to one side. I programmed it to go one way, stop, and go the other way, and that made the mouth go up and down....*"

Caroline spent a long time tinkering with engineering concepts to make the Nutcracker's mouth move the way she wanted. Her persistence and determination to succeed in her goals were not guided by her fascination with gears, but by her desire to have a working Nutcracker. Caroline can be classified as a "little storyteller"; however, in order to tell her story and build her doll, she first needed to master some engineering concepts.

During a conversation with a teacher Caroline said: "*... the hardest part was programming because first the motor went spinning around and got tangled in the wires but then we put on this fuel thing and it stopped shaking, but you still have to hold it. I learned a lot about computers and how things work.*" We do not know if Caroline will choose, as she grows up, to engage with disciplines that are closely related to engineering or to storytelling. By exposing her early on to robotic manipulatives, she can explore powerful ideas that she wouldn't have explored otherwise. She learned that, as much as she likes stories and characters, she can also enjoy building and programming, thus developing both competence and confidence regarding technological fluency.

Readiness to learn and self-confidence in our own abilities are not new ideas. However, although there is general consensus about the importance of "readiness" in literacy and mathematics, it is not clear what does it mean to achieve early readiness in engineering, programming and technological fluency. In this paper I am proposing that readiness is intimately associated with our ability to engage in the design and implementation of a personally meaningful project. For some children, in particular for the little storytellers, their interest in something else, other than technology, is likely to lead them to learn about the technology.

Kate is a first grader who loved music and bunnies. She started her project with a very clear goal: to make a rabbit. She did not like to build with Legos, neither was she interested in giving motion to her bunny. She was happy with paper and pencil. The challenge, with children like Kate, is to help them move beyond their comfort zone, while respecting their interests. Had Kate's teacher forbidden her to use paper and pencil for her bunny, it is most likely that Kate would have lost interest in the project. Little by little, while encouraging Kate to explore other materials to create a stand for her bunny, her teacher introduced her to the many possibilities that a robotic bunny could offer. Kate became interested in this and built a Lego car to support her paper and pencil bunny (see Figure 6.4).

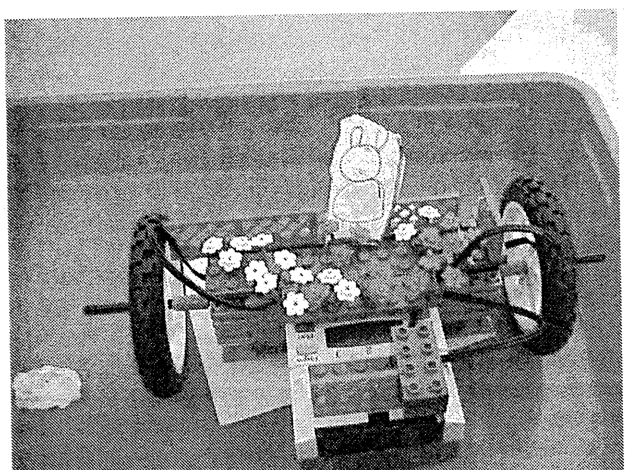

Figure 6.4. Kate's bunny.

After hard work, Kate wrote in her on-line journal:

> The Easter Bunny spins around and sings songs and it drives forward and backwards. My family celebrates Easter. It's important because it's my favorite holiday and it's my mom's favorite holiday. I had an idea. I drew a picture of an Easter Bunny and some flowers. Then I started working on it.... B. helped me program it. It goes forward, stops, and then it spins around and then you flash a light on it and it goes backwards and then it sings a song, an Easter song, and then stops. The wheels kept falling off, so I was very frustrated. Then B. said, "You need an axel extender." I got two axel extenders and it worked and the wheels stopped falling off. That was the only problem. I learned how to program. I learned how to make it spin around, play music, and stop.

By helping Kate move beyond her comfort zone of using paper and pencil, the teacher helped her to adventure into the realm of technology in which the child had no previous interest. Kate saw an opportunity in the many possibilities and flexibility of robotic manipulatives. Kate's emerging technological fluency was fostered by her interest in making digital music, not in building with the Legos or engineering.

In contrast with Kate, Max, and Caroline, the three "little storytellers" mentioned earlier, Marcos is a "little engineer." He loves to build. His project, called "speedy legs," spins and charges against another robot (see Figure 6.5). His goal was "to build a robot that would never break." This goal is an example of what differentiates little engineers from little story-

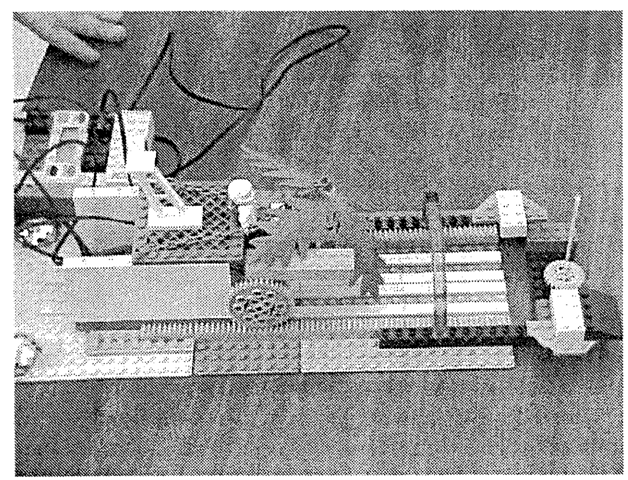

Figure 6.5. Marcos's speedy legs.

tellers. While the engineers want something sturdy that won't break, the storytellers want a story, a context, a character. Marcos explains:

> I like building. I designed it by looking at how the pieces would go together and I asked a friend when I had a problem. I programmed it by putting the speed the highest it could be. And then I did the programming and I tried it out. Then I built more and it worked. It broke when pieces fell off and that helped me learn a lot. Sometimes the blocks need to be strong. Sometimes it goes slow and sometimes it goes fast because of how I build it.

For children like Marcos, robotic manipulatives provide an early gateway into a way of thinking and a set of skills that are not learned in school until much later, if ever. Beyond providing opportunities for exploring with building sturdy structures and completing programming challenges, robotic manipulatives also offer opportunities for collaboration and teamwork, skills that will also be much needed as children grow up.

James, a first grader who is an engineer at heart, described his collaboration to make a robot with one of his classmates in the following way (see Figure 6.6):

> The big robot fighter fights and waters plants by dumping a big bucket! The big robot moves and it spins the rocket like crazy. The wheels move. It is important to Mike because almost everybody in Mike's family went in the war. It is important to me because I water the grass every summer.... We really worked hard. I did the bucket and Mike did the rocket and we worked together on the wheels and the motors. It took a really long time. We needed a little help with the motors. We worked together to decide how it would move and how it would spin the rocket and how it would stop. We took turns putting stuff on the screen when we programmed. We had problems with the rocket and the wheels and how to straighten it out. The rocket was the hardest thing. We didn't know how to attach it. We learned we had to attach the wires to the brain and the motors. We learned how to attach the rocket to a motor. We kept trying to get bigger wheels. Mike said, "Hey...Aren't we missing something?" Then we both said, "We need the big wheels!" Someone took the wheels off and we got bigger wheels. We had lots of lots of lots of fun.

Mike and James formed a productive team. In James' description of their collaboration, we can see that they sometimes chose to work together and sometimes did independent tasks. These very young children were able not only to collaborate, but also to manage their collaboration to achieve higher productivity and...fun. In the process, they learned how to program their robot, how to debug it (i.e., discover and solve problems in the code), and how engineering can be an engaging and fun experience.

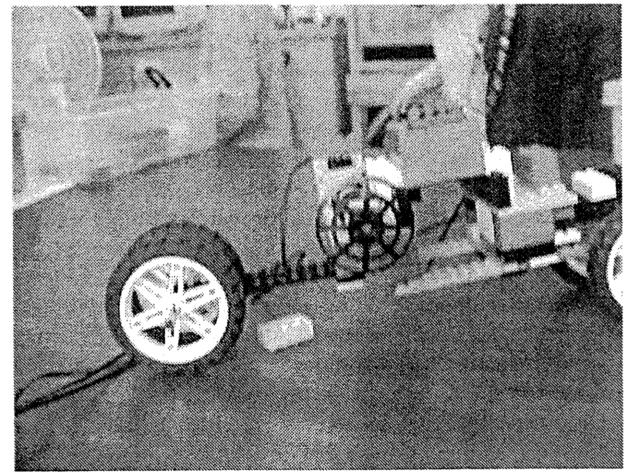

Figure 6.6. Mike and James' robot

Children like Marcos, James and Mike enjoyed using robotic manipulatives because they had an interest in engineering, although they did not know it. They engaged in the engineering design process and took upon themselves challenges to solve problems. In contrast, the little storytellers described earlier, enjoyed the work with robotic manipulatives because they could tell their stories. Both groups of children learned similar content and skills. However, had the learning environment not been set up so they could make personally meaningful projects, it is very likely that the little storytellers would have lost interest and lack motivation.

CHILDREN AND PARENTS: LESSONS FROM THE FAMILY LITERACY MOVEMENT

As shown in some of the stories presented before, children can be little storytellers and little engineers. While some tend to favor one way of knowing over the other, most young children are comfortable in both and can switch back and forth between the two roles. As children grow, some little engineers begin to label themselves as enjoying and being good at math/science and technology, while some little storytellers chose language arts and social sciences. Slowly, the gap between both ways of knowing starts to emerge and it becomes harder to help children transition with ease.

The early years are important because they set the foundation, the motivation and the readiness to later learning. However, during those early years, the role of schooling is limited in the children's lives. Learning at home is as important as learning in school. The stronger the home-school connection through parental involvement, the higher likelihood of ensuring educational success (Fan & Chen, 2001). Literacy education has been aware of this and family literacy is a growing movement in the US and abroad (National Literacy Trust, 2001; Goodling Institute, 2006). Research has shown that the practice of parents reading with their young children is a significant contributor to young children's learning to read (Teale, 1984). Some of the lessons learned from literacy education are having an impact in technology education (Wright & Church, 1986). However, while most parents are comfortable helping their children to develop literacy, the same is not true for technological fluency. How do we conceive programs to promote technological fluency in both parents and children? The family literacy movement can provide useful insights.

In the 60s, most of the studies were done following the "parent impact model" which consisted in having a teacher visit the homes and present the pedagogy and materials to the parents. Although this model proved to be successful, criticism said that this method operates in a deficit model assuming that parents lacked basic skills and methods of teaching. Later on, the success of parental involvement in Head Start led to the emergence of the Parent Education Fellow through programs that promoted diverse parental participation. The goal was for parents to become genuine partners in their child's education in whatever role suited them better (i.e., teachers, volunteers, decision makers, etc.) (Wright & Church, 1986). This approach informs my own work on Project Inter-Actions, a research program developed to understand, amongst other things, how to help parents develop technological fluency along with their children (Bers, 2004, Beals & Bers, 2006). Project Inter-Actions offers a unique opportunity to conduct research to investigate how parents can become learners at the same time as their children, while they are also providing support and guidance to them (Bers et al., 2004). Looking at parents as learners is not unique to the field of technological education and can also be found in studies of immigrants' acculturation (Jones & Trickett, 2005).

Project Inter-Actions examines the many interactions that exist when parents and young children are brought together in a learning environment fostered by new technologies that enable programming and building a robotic toy with Lego pieces and art materials to represent an aspect of the family's cultural heritage. The project's name stems from the different types of interactions looked at throughout the project: 1) interactions between adults and children together learning something that is new for both, such as robotic technology, and something that they are immersed into, such as their own cultural background, 2) interactions between abstract programming concepts and concrete building blocks, 3) interactions between ideas of what is developmentally appropriate and what children can and cannot do with technology at such early age, and 4) interactions between technology, art, and culture, areas of the curriculum that computers have the potential to integrate.

Project Interactions has been running for the last four years in the context of after-school weekend workshops for families. More than one hundred and eighty people participated so far and, amongst the many projects that were developed by the young learners and their families, it is possible to identify little storytellers and little engineers, as well as "big" ones. However, all of them, young and old, developed technological fluency by learning how to build and program their robotic projects, regardless of their favored way of knowing.

When conducting the initial background survey, 46% of the participating young children claimed that their favorite subjects at school are math and science. But only 3% declared themselves as good in math and science. Since children involved in Project Inter-Actions are first and second graders, this data is both alarming and inspirational. On the one hand, what is going on in the way math and science are taught in early childhood education, that children of such young age are already experiencing difficulties? On the other hand, almost half of the sample stated that math and science are their favorite subjects in school. This shouldn't be that surprising, given that researchers such as Piaget had long ago proclaimed that young children are "little scientists and little mathematicians." However, these first results from Project Inter-Actions suggest the need of designing educational programs to help children learn better math and science at this early age. This can be done by providing opportunities for them to make connections between abstract concepts and concrete ideas, and to help them establish personal relationships with knowledge, through the use of robotic manipulatives. Another way is to help their parents develop confidence in these areas as well, so they can support their children's early learning.

CONCLUSION

This paper suggests that we can tap the potential of young children as both little storytellers and little engineers to help them develop technological fluency. It also shows how robotic manipulatives can be used to support this work because, in the tradition of most well-known early childhood manipulatives, they engage children in learning by making, by building, by creating. They also add the programming aspect, which in today's world of integrated bit and atoms, is necessary to help young children understand how our everyday objects work, including, but not limited to, computers.

We go to the bathroom to wash our hands and the faucets "know" when to start dispensing water and when we are done. The elevator "knows" when someone's little hands are in between the doors and shouldn't close. Our cell phones "know" how to take pictures, send e-mails and behave as alarm clocks. Even our cars "know" where do we want to go and can take us there without getting lost. Robotic manipulatives provide a concrete material to start experimenting with and modeling some of these complex objects.

In the spirit of manipulative materials that has been in early childhood since Fröebel invented kindergarten in the 1800s, robotic manipulatives provide materials for children to learn about sensors, motors and the digital domain in a playful way by building their own cars that follow the light or elevators that work with a touch sensor. But even more important, robotic manipulatives are a gateway for helping children learn about abstract mathematical and science concepts in a concrete way and for helping them to develop early on technological fluency through the introduction of engineering and programming.

However, as shown in this paper, early fluency is best achieved when there is a strong home-school connection and when parents, as they do with language by reading and singing to their children before they learn these skills in school, start to immerse their very young children in a world of technology. Although multimedia applications and educational software are available and can be used to teach children new things, technological fluency is not measured by how much children learn with computers and how many new skills they develop, but by children's ability and confidence to use computers and other technologies (such as robotic manipulatives) to be able to create their own personally meaningful projects. On the way, they will probably be learning new concepts and skills, but most important, they will be able to see themselves as good learners. With the continuous advances in new technologies and applications, learning how to learn is the only viable recipe for success.

This paper also suggests that the field of technological education in early childhood has much to learn from the family literacy movement to involve parents in the early years. However, if the work is done without respecting the different ways of knowing, in both children and adults, it is very likely that we will lose the little storytellers in the way and only attract the little engineers. Early childhood is a time of fluidity and experimentation between roles and epistemological styles. While most ways of using technological tools such as robotics, focus on little engineers who will grow into big engineers, this paper advocates for the importance of respecting and inviting different ways of knowing and motivations while working with robotic manipulatives. But the pedagogy with which the tools are used is as important as the tools themselves. Thus this paper has focused on the constructionist philosophy of learning and its tenet that people learn better while using technology to build concrete meaningful projects to establish personal connections with abstract ideas.

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