Designing Technology for Children: Moving from the Computer into the Physical World with Electronic Blocks

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Electronic Blocks are a new programming environment designed specifically for children between three and eight years of age. As such, the design of the Electronic Block environment is firmly based on principles of developmentally appropriate practices in early childhood education. Electronic Blocks are the physical embodiment of computer programming. They aim to have the unique programmable properties of a computer minus its complexity, thereby allowing children to explore programming concepts in an intuitive and meaningful manner. The Electronic Blocks are physical, stackable blocks that include sensor blocks, action blocks, and logic blocks. By connecting these blocks children can program structures that interact with the environment. A six-day evaluation with over 30 preschool children showed that the blocks’ ease of use and power of engagement created a powerful tool for the introduction of meaningful technology education in an early childhood setting. The Electronic Blocks provide opportunities for open-ended, discovery-oriented play, that a screen and keyboard can never provide.

Electronic Blocks are blocks with electronic circuits inside them. Designed specifically with young children in mind, Electronic Blocks provide a computer interface which children can carry, stack, and balance. By placing Electronic Blocks on top of one another, young children build “computer
programs”—each stack of Electronic Blocks is capable of a different function. Using the blocks children are able to create robots that crash into each other, creatures that sing in the dark, and lights that flash when you clap. The sensors and effectors built into the blocks allow children to build structures that interact with the environment. The sensor blocks detect light, sound, and touch while the effector or action blocks are capable of producing light, sound, and movement. The inclusion of logic blocks—blocks that logically negate, delay, and toggle signals between blocks—adds an additional dimension to the capabilities of the children’s creations. By connecting sensor blocks with action blocks children can program their own structures. They might create a group of “robots” and these robots might wink at each other, move when they hear sound, or be capable of following a light.

Electronic Blocks aim to provide young children between three and eight years of age with opportunities to explore technology in a purposeful and appropriate way. The development of these blocks is a response to growing concerns about the provision of developmentally appropriate technology education within early childhood settings. The following section describes three fundamental assumptions that form the motivation for Electronic Block design. Aspects of the fundamental assumptions in turn form the design criteria for the blocks. The design criteria are used in two ways. Naturally, they form the basis for the functional design of the Electronic Blocks. The functional design is described in detail in a subsequent section. The design criteria are also used as a reference frame for an evaluation of the effectiveness of the blocks. Evaluation data is presented from videotaped observations of children using the Electronic Blocks in a preschool setting. The evaluation of the blocks against the design criteria illustrates that the blocks are an effective tool for technology education in the preschool classroom.

FUNDAMENTAL ASSUMPTIONS

It is important to establish the motivation for the introduction of a new technological tool for use in early childhood settings. The design of Electronic Blocks has been based on three assumptions:

1. Technology education is an important aspect of early childhood education.
2. Young children can best benefit from a developmentally appropriate introduction to technology education.
3. Exploring programming concepts offers unique and meaningful technology education experiences.
These assumptions represent the culmination of ideas that have grown through an understanding of current literature in the areas of early childhood development and learning, technology, and technology education. The following sections examine each of the three fundamental assumptions in detail.

### Technology Education is an Important Aspect of Early Childhood Education

For the last decade many educational committees, associations, and councils have highlighted technology education and its emerging importance in future educational programs. As early as 1983, the National Commission on Excellence in Education (1983) was looking at the necessary role of technology in the basic education of every school student in the United States. Within Australia, the Australian Education Council (1992, 1994) and the National Board of Employment, Education, and Training (1993) have been examining the impact of technology on people’s lives and determining the role technology should play in schools. The National Association for the Education of Young Children developed a position statement (1996) on technology education and young children in response to the growing significance of technology in today’s society.

This interest in technology education has stemmed from a growing awareness of the potential of technology in enhancing the quality of every person’s life. Technology is contributing to worldwide changes in cultural, social, environmental, and economic circumstances. It is altering perceptions, attitudes, and values. Knowledge of technology is vital in that it:

- allows us to understand the processes that bring about technological inventions and change;
- increases our ability to deal with and use the products of technology effectively;
- allows us to make informed decisions about the sustainable development of technology; and
- opens up employment opportunities in many fields.

Given the significance of technology as we move into a new millennium, it is understandable that parents are growing increasingly concerned about the technology education their children are receiving. Educational institutions need to promote children’s ability to cope with the escalating technological demands of society, and technology education needs to prepare students for living and working in a technological world. As a result,
technology education is increasingly becoming a concern for educators at all levels.

In the specialist area of early childhood education there is a continuing challenge for educators to develop educational programs that recognise and respond to the impact of the “information revolution.” As a result, more and more educational institutions are introducing technology to young children. Exposure of young children to computers in early childhood settings is growing markedly (Fatouros, 1995) as the potential benefits of technology for young children’s learning and development are increasingly documented (Wright & Shade, 1994). In general, the emphasis in technology education has been on the computer and other technological artefacts (Mackay, 1991). As computers become easier to use and quality early childhood software becomes more readily available, young children’s use of computers becomes more widespread (National Association for the Education of Young Children, 1996).

**Young Children Can Best Benefit From a Developmentally Appropriate Introduction to Technology Education**

Developmentally appropriate practice is recognised as the guiding concept behind high quality early childhood education (National Association for the Education of Young Children, 1987). It is advocated by early childhood professionals to ensure that young children’s learning experiences are age appropriate, individually appropriate, and culturally appropriate.

As Hitz (1992, p. 310) outlined, there are two basic assumptions underlying developmentally appropriate practices.

1. Young children have somewhat different physical, social, emotional, and learning needs than older children and adults.
2. There are individual differences that should impact teaching practices. Same-age children vary widely in their rate of development, interests, aptitudes, temperament, and experiences.

As early childhood education is dedicated to providing developmentally appropriate experiences for young children (National Association for the Education of Young Children, 1987), the design of a developmentally appropriate resource must consider the nature of young children and how they learn.

There are many theories, perspectives, and approaches to studying children’s development and learning. Currently, the field of education is embracing a constructivist approach to learning (Sprung, 1996), which takes
the position that knowledge is neither a copy of the external world nor a reflection of preformed structure in the mind. Rather it is built up over time as the result of constructive action (Lee, 1992). Constructivism implies that people are active seekers and interpreters of their experience, not merely reactors to stimulation from the environment. Piaget developed the theory of constructivism and he:

tells us again and again that knowledge does not come to us from outside, “ready-made.” It is not a “copy” of reality—not just a matter of receiving impressions, as if our minds were photographic plates. Nor is knowledge something we are born with. We must construct it. We do this slowly over many years. (Donaldson, 1978, p. 140)

Piaget and other cognitive developmental scientists saw people as active agents who construct their own understanding of the world (Fischer & Lazerson, 1984).

From a Piagetian perspective, children between three and seven years of age are moving through the preoperational stage of cognitive development. Piaget used the word preoperational to describe thought that occurs before children are capable of what he called operations, or schemes of connected relational reasoning (Fischer & Lazerson, 1984).

The preoperational stage is characterised by children who:

1. begin to use semiotic systems such as language and imagery; and
2. lack operational thought—flexible reversible reasoning which allows them to conserve, classify, seriate, coordinate perspectives, and overcome misleading perceptual impressions (Meadows, 1993).

During this time the child’s symbol system expands (Santrock, 1983) and thinking becomes representational (Fromberg & Gullo, 1992). Representational thinking, in cognitive development theory, describes the ability of children to think about properties of things independently of their direct actions on them. Preoperational intelligence often lacks logic and generally children are not capable of operational thought which is distinguished by what Isaac describes as “schemes of connected relational reasoning” (Fischer & Lazerson, 1984). Their actions and thoughts are limited by intuitive thinking.
Preparing young children to live in a world where they may be required to interact with technology daily is a challenge for all early childhood educators. This challenge comes in the face of skepticism about the appropriateness of computers—at present the most popular means of introducing young children to technology—in early childhood settings (for a review of literature in this area see Bailey and Weippert, 1991; Yelland, 1997). Some of the concerns of educators have stemmed from inappropriate use of computers in early childhood classrooms. While there is considerable research that points to the positive effects of computer use on children’s learning and development (Clements, 1994; Shade & Watson, 1990), computers, like any tool or resource, can be misused (Shade & Watson, 1990).

The provision of computers alone does not ensure that children’s needs with respect to technology education are being met. Unfortunately, the use of computer laboratories in primary schools, the provision of vocational courses that use sophisticated equipment, and the use of computer-based laboratories in science, are often cited examples of technology education in practice (Raizen, Sellwood, Todd, & Vickers, 1995). All too often, the computer is used as a panacea in the rush to implement technology education in our schools. Generally, both students and teachers believe that technology means computers (Raizen et al., 1995) and that technology education involves learning how to use computers (Mackay, 1991). Whether or not the computer is providing learning opportunities that are appropriate and meaningful appears, all too often, to be a secondary consideration.

Yelland (1997) identified two ways in which technology could be used in early childhood education. In the first instance, technology can be used to reinforce existing practices—a generally mechanistic process that reinforces curriculum content and facilitates activities such as reading, writing, and mathematics. Computers in such environments act as electronic workbooks. This style of computer use has led to educators asking whether or not computer-based activities offer anything that is substantially different from what can be obtained in the classroom by other means (Sheingold, 1987; Cuffaro, 1984; Sloan, 1984).

The challenge for educators is to determine how the computer could be made more interesting, appropriate, and useful to young children. In identifying a second way in which technology can be used in early childhood education, Yelland (1997) looked towards computer environments that were stimulating and encouraged active exploration of objects and ideas. Such
computing environments enable the computer to be confidently used to facilitate quality technology education—it becomes a resource, which allows young children to be involved in the design and production processes to produce various outcomes.

Raizen et al. (1995) proposed that good technology education requires students to use intellectual and physical resources (knowledge, tools, materials, and information) while involved in processes (designing, producing, and using) to produce outcomes (products, structures, and systems). Sheingold (1987) extended this idea by proposing that in an early childhood setting, children should explore the computer’s unique dynamic and programmable properties. It is these properties which make it different from other media with which children interact. The stance taken in the research reported here is that although computers can have many functions within an early education setting, its power as a tool for technology education lies in the programming and dynamic properties unique to it. Resnick et al. (1996) proposed that programming a computer is a far richer experience than any other that may be provided through computer use. They asserted that through learning to program a computer, children develop a much deeper relationship with (and deeper understanding of) the computer (Resnick, Bruckman, & Martin, 1996). Exploring the dynamic and programmable properties of a computer allows children to become creators, not just consumers, of computing activities.

The concept of programming as a rich educational experience is hardly new. The well-established Logo programming language (Papert, 1980) enables children to write procedures to manipulate a “turtle” on a computer screen. Logo was developed as an educational resource, which incorporates some of the essential elements of Piaget’s theory, which holds that children are builders of their own intellectual structures and that intellectual development does not always need explicit teaching (Vaidya, 1984).

Logo, although designed specifically for educational purposes, has rarely been used with children under the age of six or seven. Logo research projects, to a large extent, have involved older children (Hughes & Macleod, 1986). This lack of research with young children is not surprising as many of the ideas involved in Logo, such as that of a variable, or recursion, would be difficult for young children to grasp. Even the basic commands of Turtle Graphics, such as FORWARD 100, or RIGHT 90, involve not only relatively large numbers but also ideas about length and angle, which young children may not yet have encountered (Hughes & Macleod, 1986).

In more recent years, a number of other interactive programming environments have been developed for use by young children (Kahn, 1996;
Smith, Cypher, & Schmucker, 1996; Resnick, 1993; Frei, Su, Mikhak, & Ishii, 2000), with the aim of enhancing cognitive skills. While all seek to enable children to use the dynamic and programmable properties of the computer, all rely on abstractions to and/or from the computer screen and keyboard to the physical world. In other words, none have both physical inputs and outputs for the programming environment (with the exception of curlybot (Frei et al., 2000)). To provide suitable programming experiences for the sensory dependent young children, both the method of programming and the outcome of the program must be made tangible. This idea is explored further in the following section, which defines how these fundamental assumptions about developmentally appropriate technology education for young children may be turned to a set of meaningful design criteria for a new technology resource.

**DESIGN CRITERIA**

Given the discussion from the previous section, the question arises—“How do we make programming experiences developmentally appropriate?” Unfortunately for young children, the ideas about instructions and sequence, which form the core of programming, are not necessarily simple. At a time when young children are just acquiring the rudiments of notational systems and are struggling with symbolisation in language, it would be unreasonable to expect them to cope with the symbolic systems required to successfully program a computer. Such symbolic systems are too complex for young children to fully understand (Sheingold, 1987).

As an alternative to the computer, Electronic Blocks are designed to provide preschool and early primary school children with a resource that has the unique dynamic and programmable properties of a computer, minus its complexity. Electronic Blocks are the physical embodiment of computer programming. They are naturally less complex to program than a computer as they do not require a knowledge of complex symbolic systems.

The design of the Electronic Blocks is based on the belief that a technological resource that is designed specifically for children under eight can offer powerful learning opportunities previously unavailable to young children. Consequently, the focus of this research is on developing an alternative resource to the most popular means of introducing young children to technology at present: the computer. It is intended that this new resource will be more developmentally appropriate than the computer. The specific developmental needs of young children have been considered in the design of Electronic Blocks.
To meet the requirement to be developmentally appropriate, the Electronic Blocks have the following design criteria, based on Bredekamp and Copple’s (1997) criteria for developmentally appropriate practice:

- activities are open-ended and discovery-oriented, allowing children to be actively involved in the learning process;
- interaction encourages child-initiated play;
- experiences involve active manipulation and transformation of real materials;
- entry level knowledge and experience is kept to a minimum;
- provision is made for children’s varied skill and ability levels; and
- construction activities that involve the design, creation, and evaluation processes form the basis of interactions.

These criteria form the basis for the functional design of the blocks (described in the next section) and act as a reference frame for the evaluation of the blocks. The effectiveness of the Electronic Blocks may be established by examining the evaluation data against the design criteria.

The second perspective of the design of the Electronic Blocks is as an alternative to the computer. Electronic Blocks are designed to provide preschool and early primary school children with a resource which has the unique, dynamic, and programmable properties of a computer, minus its complexity. A constructivist approach to programming forms the basis by which this goal is achieved. Electronic Blocks are designed to allow children to be active participants in programming activities, ensuring concrete interactions are the primary means by which children explore the dynamic programmable properties of the blocks.

To create a programmable resource, Electronic Blocks have been designed using guidelines outlined by Resnick (1987). They are designed to:

- be nonalgorithmic—the path of action is not fully specified in advance;
- be complex—the total path is not visible;
- incorporate uncertainty—not everything that bears on the task at hand is known;
- allow users to find structure in apparent disorder; and
- yield multiple solutions, each with costs and benefits.

Electronic Blocks aim to provide young children with a physical construction tool that they can use to create their own dynamic systems. Young children who are not yet able to read or write should be able to explore new
concepts of programming and control by manipulating and transforming real materials. The following section describes how the functional design of the blocks simultaneously meets the design criteria of a developmentally appropriate resource and the guidelines for creating a programmable artifact.

Functional Design

The Electronic Blocks have been designed so children can connect them just as they would any other blocks. The blocks have been made by placing electronics inside Lego Duplo Primo™ blocks. This ensures that the blocks are easy to stack and connect, and present a familiar physical interface to many children. The blocks have inputs and outputs and when connected, the output of one block controls the input of another. Electronic Blocks can be connected together to create a wide variety of dynamic structures which interact with the environment. Different behaviours may be observed by connecting two or more blocks together. There are three kinds of Electronic Blocks: sensor blocks, action blocks and logic blocks (Figure 1).

Figure 1. The complete Electronic Block family: the three sensor blocks are to the left (seeing at the front, touch in the middle and hearing at the rear), the four logic blocks are in the centre (toggle at the front, not in the middle and delay at the rear next to the double and block), and the action blocks to the right (sound at the front, with the light and movement at the back).
Sensor Blocks

There are three sensor Electronic Blocks: a *seeing* block, a *hearing* block and a *touch* block. These blocks are capable of detecting light, sound, and touch, respectively. They are single connector blocks that have an input from the block above and an output to the block below (Figure 2). The input from the block above is off if there is no block above or the block above is not sending a signal. The input and the sensor are logically ORed together to produce the output: output is produced if there is input present from another block OR there is a signal from the sensor. As a result when two or more sensor blocks are stacked on an action block any sensor input will trigger the block below.

![Figure 2. Functional diagram of a sensor block. Either sensory input or an active signal from the block above will cause the output to be active.](image)

All sensor blocks are yellow. This makes the important sensor functionality easy to locate for block stack builders. The different functions of the sensing blocks are identified by readily understandable icons: for example, an eye for a *seeing* block.

**Action Blocks**

Action blocks produce some kind of physical output. The *light* block lights a bright incandescent bulb, the *sound* block plays a simple children’s melody, and the *movement* block is a four wheel car that drives in a straight line.
All action blocks have two inputs from the blocks above. If either input is triggered the block will act. They are physically constrained by a base plate so that they cannot be placed on top of another block and have to be positioned at the bottom of a block stack. Figure 3 shows a light block under a touch block.

The functionality of the action blocks is somewhat self-evident from the physical structure of the blocks. The sound and light blocks are also adorned with explanatory icons.

Figure 3. A touch block attached to a light block will cause the light to turn on whenever the sensor plate is touched.

Logic Blocks

Logic blocks have an intermediary role. Placed between a sensor block and an action block they have the ability to alter the expected action. Logic blocks provide users with the capability to:

- produce an action if a particular stimulus is not received (not);
- toggle the input so that in the first instance the stimulus from the environment will “turn the action on” and the second instance of the stimulus will “turn the action off” (toggle);
- stretch a short signal so that the action will stay on for two seconds after the stimulus stops (delay); and
- only produce an action if input signals are received simultaneously through both inputs (and).
With the exception of the *and* block, these blocks are single connector blocks with an input attached to the upper connector and an output attached to the lower connector (Figure 4). The input of the blocks is off when no block is connected to the input. The *and* block, a double connector block, has two upper connectors which may receive an input signal. The block works as a logical AND—it must receive an input from both connectors to produce an output. The output signal produced is attached to both lower connectors.

![Figure 4. A NOT logic block placed between a sound sensor block and a light block performs a logical NOT operation causing the light to go on whenever there is no sound.](image)

Each different logic block type has distinctive icons and colours to assist their identification. It is difficult to choose meaningful icons for these blocks. What icon explains “and” to a preschooler? The icons were chosen to have readily understood adult meanings: for example, “&” for “and.”

**Programming with Electronic Blocks**

The Electronic Blocks are designed so that by simply playing with the blocks, children can produce interesting behaviours that they find fascinating. They might build a block tower that flashes when they talk, or moves with their touch. These are examples of simple sensor-action combinations. Given a set of three sensor blocks and three action blocks, there are a total of nine such combinations.
The addition of logic blocks to the set of Electronic Blocks opens up a wide variety of additional construction opportunities. A task that sees the introduction of a logic block is the creation of a car that starts when you clap and stops when you clap again. A `toggle` block placed between a `hearing` block and a `movement` block will achieve this result. Logic blocks add to the complexity and variety of structures that may be created.

A fascinating aspect of Electronic Blocks is their ability to interact not only with the environment but also with each other. An example of two Electronic Block structures interacting is the creation of a remote control car. By creating one block stack which contains a `touch` block and a `light` block and another stack which has a `seeing` block on top of a `movement` block, a child has effectively created a remote control car. By pressing the `touch` block, the child triggers the light. This light in turn is detected as an input by the `seeing` block which actives the `movement` block (Figure 5).

![Figure 5.](image)

Figure 5. A remote control car demonstrates interaction between block stacks. The `touch` block on the `light` block forms the remote control for the car formed by placing a `seeing` block on a `movement` block.

It is apparent from this functional design that the Electronic Blocks have the potential to meet the requirements of a developmentally appropriate programming artifact for young children. The subsequent section details the evaluation that was carried to establish the block’s capabilities with regard to the stated design criteria.
PRESCHOOL EVALUATION

From an evaluation perspective, this article focuses on the extent to which Electronic Blocks were shown to be a developmentally appropriate resource for young children. Therefore the analysis of the evaluation data focuses on determining whether the children can use the Electronic Blocks easily, whether they enjoy using the Electronic Blocks and whether they understand what they were doing with the blocks. Specifically, the data should illustrate whether the blocks:

1. encouraged open-ended and discovery-oriented play;
2. encouraged child-initiated play;
3. provided opportunities for active manipulation and transformation of real materials;
4. facilitated minimum entry level knowledge and experience;
5. provided for children’s varied skill and ability levels; and
6. encouraged construction activities that involve the design, creation, and evaluation processes as the basis of interactions.

These statements reflect the key design criteria established earlier for a developmentally appropriate resource. This section describes the method and setting for the evaluation of the blocks, and highlights key observations and metrics to be used in the later analysis of the data against the design criteria.

Evaluation Methodology

The preschool evaluation of Electronic Blocks took place at an on-campus university preschool. Twenty-eight children between 4 and 6 years of age participated in the evaluation. Six experimental sessions spanning two weeks were conducted and each session lasted between 60 and 90 minutes.

The Electronic Blocks evaluation in the preschool environment used direct observation methods of data gathering. These methods primarily involve naturalistic observation. In general, it is acknowledged that observation is the only practical research process in early childhood education as it provides a more realistic picture of behaviour or events than do other methods of information gathering (Irwin & Bushnell, 1980; Medinnus, 1976; Hutt & Hutt, 1970; Brandt, 1972). Direct observation involves observing behaviours or events occurring in natural settings without trying to control or manipulate factors that might influence the behaviour being studied (Irwin & Bushnell, 1980). It aims to study freely occurring behaviour in natural settings where there is nothing artificial or contrived.
At each session the Electronic Blocks were set up in an area within the indoor play area. Three complete sets of Electronic Blocks—30 blocks in total—were provided at each session. A video camera and audio equipment were used to record children’s interactions with the blocks. All children within the preschool room were free to participate in the study. However, due to the number of Electronic Blocks available, a limit of four children using the blocks at any time was imposed. The investigator actively participated in all evaluation sessions, providing children with ideas on how they might use the blocks, answering their questions and helping them to solve problems. During the informal free-play sessions the investigator showed any new participants examples of simple sensor-logic-action block combinations and explained the functionality of each of the blocks.

Patterns of Usage

Of the 31 preschoolers who attended the preschool over the period of the evaluation, 28 chose to participate. Of the preschoolers who used the Electronic Blocks, 71% used the blocks on more than one occasion. Of the remaining children 50% were unable to return for a follow-up session, as they were only at the preschool for one day of the evaluation. Children on average played with the blocks between two and three times during the six days of evaluation. Five of the 28 children returned four times.

The average amount of time each child spent playing with the blocks in a single session was 15 minutes. The longest time spent playing with the blocks in one session was 47 minutes while the shortest length of time was three minutes.

The average amount of time each child spent playing with the blocks over the entire evaluation period was 33 minutes. The minimum amount of time spent with the blocks was 5 minutes, while the maximum was 1 hour and 39 minutes.

Productivity

The “productivity” of each child using the blocks was determined based on a preliminary analysis of the video data. Productivity was calculated as the number of working block stacks children built during their time interacting with the blocks. The video evidence shows that on average each child built a working block stack every two and a half minutes. While two
children failed to build anything during the evaluation period, other children built block constructions at an increased rate. Two children managed to build a working construction every minute they were involved in the evaluation. Construction included adding a block or blocks to an existing stack or creating a stack from scratch.

It is interesting to note that while some children were avid builders others were content to build one particular structure and play with that for a long period of time. One example of note is where a one child built a remote control car and then played with it for 15 minutes.

Another noteworthy issue is that three of the children were primarily interested in building interesting structures with the blocks with no consideration for what the outcome would be. The more blocks they could pile on top of one another the better. In one session, one child went a step further and added other articles from the environment—a piece of mesh found on the floor, a bell from the music area, and a piece of string.

**Types of Construction**

The children were involved in a wide variety of construction activities. The *movement* block was the favorite output block followed closely by the *light* block. All children who interacted with the blocks, at some stage in their construction activity created a moving vehicle of some kind. Children used the seeing, hearing and touch blocks to activate the movement blocks, and many were successful at creating a “remote control” car using a *seeing* block attached to the *movement* block and then activating a separate *light* block to make the car move. This became very popular and for over 70% of the evaluation period at least one of the children was playing with a remote control vehicle that they had built.

The construction complexity varied greatly. While a majority of children were primarily constructing simple input and output combinations, there were also many examples of children using logic blocks in the construction activities. Three quarters of the children who returned to the blocks on more than one occasion used logic blocks at some time.

A large majority of the constructions undertaken by the children contained either two or three blocks. The addition of further blocks, particularly logic blocks, in many cases confused the children, and for the most part children seemed to avoid building large stacks of blocks once they understood how they worked. The data captured shows that initially children were willing to build large stacks with four or five blocks, but this tended to
drop off once children began to grasp the functionality of the blocks. There were some children, however who were not concerned with the output they produced and the act of construction was their motivation for taking part. In these cases the children tended to build elaborate stacks of blocks, the largest stack consisting of thirteen blocks.

Understanding Block Functionality

The video footage provides clear evidence that the children are, in general, able to understand the functionality of the sensor and action blocks. However, there are examples of misconceptions in this area. The most common error involved children trying to get an action block working without a sensor block attached, or children trying to trigger a sensor block attached to an action block with an inappropriate signal (e.g., triggering a hearing block with light). The investigator constantly stressed to the children the need to have a “yellow block” (a sensor block) in their stack.

Many of the children struggled with the functionality of the logic blocks. The \textit{and} block was used on very few occasions and in those instances when it was used, it was used to create either giant block stacks with no clear purpose or its use was instigated by the experimenter. The \textit{delay} block was used sparingly.

The children, especially those who returned on more than one occasion, used the \textit{not} blocks and the \textit{toggle} blocks effectively. The \textit{not} blocks were useful in that they created more action than they stopped, making more dynamic and interesting creations. The \textit{toggle} blocks were set up as effective on-off switches.

The children especially enjoyed creating interacting block stacks, remote control cars, in particular. The enjoyment seemed to stem from the complexity of their construction. The children felt empowered to have made an artefact with many interacting elements.

Group Time Questions

A group of 25 children were asked their views on the Electronic Blocks on the final day of the evaluation. The investigator asked “who thought the blocks were fun to play with.” All the children, bar one, raised their hands. They were then asked whether they thought the blocks were a “bit tricky.” Ten children raised their hands.
When asked what they thought was the best thing about the blocks the three main responses were:

- the cars (four children);
- the remote controls (three children); and
- the torch (two children).

In response to ways that the blocks could possibly be improved, suggestions included:

- making the cars go faster;
- making the music louder;
- having radio music;
- using earphones to hear the music;
- having more building blocks; and
- making a bus or an aeroplane.

**ANALYSIS**

This section ties the preschool evaluation data to the design criteria for a developmentally appropriate resource. By examining each criterion individually, clear conclusions may be formed regarding the Electronic Block’s appropriateness. Also, comparisons are made between the Electronic Blocks and their desk-bound counterpart: the computer.

**Open-ended and discovery-oriented play.** The extent to which children were involved in open-ended and discovery oriented play is assessed largely by the types of construction undertaken by the children. The children were able to construct a vast number of different types of vehicles, robots, and other creations. The blocks were suitable for different interaction styles. Some children liked to create a single construction and then play with it for an extended period of time. In contrast other children enjoyed creating, adding to creations, pulling creations apart, and then building something else. A small number of children were content to watch other children play with the blocks. Some children built with the express purpose of creating a particular “thing” while others were more interested in the act of construction, building great towers with the blocks.

Children were able make discoveries about different constructions. There were many examples of children building a structure with no particular purpose in mind and then working through the process of discovering
exactly what their structure “could do.” Much of the interactions with the blocks involved the children observing the output produced by the blocks given a specific input. This turned the children into scientists and engineers, making observations, creating experiments, exploring limitations, and designing new structures.

**Child-initiated play.** The design of the Electronic Blocks means that there was no “wrong answer” only unexpected outcomes and as a result children were able to build constructions without a great deal of intervention. In general, the children’s interactions with the investigator involved asking questions when they were having difficulty understanding the functionality of a particular block. As the evaluation progressed the children developed a simple understanding of how the blocks worked and were increasingly able to initiate the construction process.

Over the period of the evaluation, 28 out of the 31 preschoolers in the centre voluntarily played with the Electronic Blocks. The average amount of time spent with the blocks over the six sessions, was 33 minutes per child. All sessions took place during free play periods, indicating that most children felt confident initiating play with the blocks. A majority of the children also choose to play with the blocks on more than one occasion, with most children participating in the evaluation two or three times.

**Active manipulation and transformation of real materials.** The link to this design criteria hardly required evaluation. The blocks and their method of use are inherently real. It was interesting to note that some children used the blocks to interact with other real materials from the preschool setting in the construction of block towers.

**Facilitated minimum entry level knowledge and experience.** Of the 28 children involved in the Electronic Block evaluation, only three failed to gain an understanding of the functionality of the sensor blocks and the output blocks. Most of the participants quite happily stacked and balanced the Electronic Blocks and as a result became familiar with their simple functionality. The children experienced Electronic Blocks in the same manner they experience any other construction material. As a result of simply playing with the blocks, children unintentionally produced interesting behaviours that they found fascinating. They asked questions, used trial and error, and appeared to delight in the simple behaviours they were able to produce.

It is apparent that the entry level knowledge required to use the blocks is comparable to other early childhood activities. Engaging outcomes are
achievable from the simplest construction, providing opportunities for further exploration and learning.

**Providing for children’s varied skill and ability levels.** The three children who did not gain an understanding of the basic sensor and output blocks represent those with the least level of skill in Electronic Block play. These children were content to watch other’s building with the blocks, but did not feel inclined to do so themselves. The children did not engage in the constructivist learning process, which appears the principle reason for their lack of ability with the blocks. This emphasises the importance of engagement in developing understanding. Even so, the children participated in the social aspects of the block building group, and were content just to observe.

While some children only became familiar with the input and output blocks, 15 of the 20 children who used the blocks more than once developed a basic understanding of the logic blocks, with *not* and *toggle* blocks being used extensively during the evaluation. The blocks were able to provide challenges and extensions as children were prepared to explore the functionality of the logic blocks. In addition, the children tended to build complexity by creating interacting block structures.

There is potential for the blocks to be used with children with greater skill and ability levels than evaluated in the preschool setting. The *delay* and the *and* blocks require a deeper understanding of the block function, but open up new creative possibilities. Ad-hoc evaluations with adult participants show Electronic Blocks to be engaging and challenging through a range of age and skill levels.

**Construction activities involved the design, creation and evaluation processes.** The blocks allow children to be active participants in design and construction activities, ensuring concrete interactions are the primary means by which children explore the dynamic properties of the blocks. Electronic Blocks put children in the driver’s seat, through providing an open-ended, discovery-oriented vehicle with which to work. Such a process-based approach is ideal for enhancing technological capabilities, given the previously stated definition of technology (Raizen et al., 1995) with its emphasis on the design and production processes.

The evaluation also clearly showed that the preschoolers reflected on their creative experiences to build their knowledge and understanding of the blocks. The children’s evaluation process was apparent not only from the self-discovery of knowledge, but also from the verbal and body language used as the children observed the behaviours of their creations.
Comparison with the Computer

While there are ways in which computer use may be adapted to ensure it is developmentally appropriate for children under eight, difficulties arise as a result of its inherently symbolic nature. Ensuring that children using computers are making meaningful connections between the symbol system of the computer and the ideas the symbols represent is difficult. To achieve these kinds of connections, children must be actively constructing relationships through interactions with a responsive system that gives feedback and encourages further investigation. While these kinds of interactions are easily achieved using Electronic Blocks—indeed, any other kind of interaction would be impossible—very few early childhood software programs offer opportunities for active, responsive, open-ended interaction.

Table 1 summarises the various ways in which developmentally appropriate practices have been considered (Suri, 1997) and makes a comparison between how a computer meets these considerations and how they have been met through the design of Electronic Blocks. The table outlines the unique attributes of children—their styles of play, how they develop thinking and problem solving skills, their love of open-ended activities that encourage independence—and shows how the Electronic Blocks meet the developmental needs of young children far better than the personal computer.

CONCLUSIONS

Electronic Blocks are developmentally appropriate resources for technology education in early childhood settings. In a world that places growing emphasis on the importance of technology for everyday interactions, it is especially important that children have positive experiences with technology. Electronic Blocks address concerns about young children’s physical and cognitive readiness to use computers by making the traditional interface disappear—to be replaced with a tangible interface that is both familiar and powerful. The educational power of the blocks is derived from their role as a programming environment, enabling young children to become creators rather than users of technology. With little or no entry-level knowledge required to use the blocks, children quickly become absorbed in the fascinating world of computer programming.
### Table 1
**Electronic Blocks Versus the Computer: A Comparison of Developmental Appropriateness**

<table>
<thead>
<tr>
<th>“Things about Kids”</th>
<th><strong>Electronic Blocks</strong></th>
<th><strong>Computer</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Play in general involves communication and cooperation with others.</td>
<td>The blocks facilitate both solitary and group interactions.</td>
<td>Computer play tends to be a solitary pursuit.</td>
</tr>
<tr>
<td>Play is essentially physical—it involves multi-sensory experiences in the exploration and formation of concepts.</td>
<td>Children can physically manipulate the blocks—using the blocks is a rich kinaesthetic experience.</td>
<td>Although programs can offer visual and auditory richness, repetitive button pushing of a keyboard and mouse are impoverished forms of tactile interaction.</td>
</tr>
<tr>
<td>By manipulating objects young children develop perceptual and motor skills.</td>
<td>Electronic Blocks allow direct manipulation of objects.</td>
<td>The computer only allows the “virtual” manipulation of objects.</td>
</tr>
<tr>
<td>Thinking and problem solving skills develop through children constructing and creating.</td>
<td>Electronic Blocks encourage construction and creation activities.</td>
<td>Only some computer programs focus on creative activities. Often software is mechanistic and allows very little user control or initiative.</td>
</tr>
<tr>
<td>Most successful and enduring activities are open-ended, allowing children to combine and organise elements, to create patterns, events, stories, and games.</td>
<td>Like any blocks found in the early childhood environment, Electronic Blocks allow for a wide variety of open-ended play opportunities.</td>
<td>With computers children can only progress serially from one exclusive application environment to another.</td>
</tr>
<tr>
<td>Children need to access activities independently.</td>
<td>Children can use the blocks independently—things might not always work out but it is easy enough to pull them apart and start again.</td>
<td>The computer generally requires a high degree of adult supervision—software flaws or a wrong button press will abruptly end a game.</td>
</tr>
</tbody>
</table>
References


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