The Principles of Educational Robotic Applications (ERA)

A framework for understanding and developing educational robots and their activities

Dave Catlin, *dave@valiant-technology.com*
Valiant Technology Ltd. 3 Grange Mills, Weir Road, Balham, London SW12 0NE

Mike Blamires, *michael.blamires@canterbury.ac.uk*
Dept of Education, Canterbury Christ Church University, Canterbury, Kent, CT1 1QU

Abstract

The original educational robots were the Logo Turtles. They derived their rationale from constructionism. How has this changed? This paper postulates ten principles that underpin the effective utilisation of robotic devices within education settings. We argue that they form a framework still sympathetic to constructionism that can guide the development, application and evaluation of educational robots. They articulate a summary of the existing knowledge as well as suggesting further avenues of research that may be shared by educationists and designers. The principles also provide an evaluative framework for **E**ducational **R**obotic **A**pplications (ERA). This paper is an overview of the ideas, which we will develop in future papers.

Keywords

Educational Robotics, Constructionism, HRI, HCI, Robotic Applications, Machine Mediated Learning, Cross Disciplinary Research, Collaboration, Logo, Roamer, Turtle, ERA, STEM.

Introduction

Logo combines philosophy, educational theory, artificial intelligence, cognitive science, developmental theory, neuroscience, robotic engineering and computer science. It emerged in the 1960s when most of these disciplines were still in their infancy. Post modernism, logical positivism, phenomenology and deconstructionism were disrupting age old philosophical positions. Turtles, the first breed of educational robot, emerged as part of Logo and shared its intellectual grounding particularly its constructionist approach to education. While the intervening years have seen significant developments in the underpinning sciences, little has been done to review their overall and collective impact on the way we use educational robots.

While never becoming extinct, real Turtle robots faded into the background as researchers almost exclusively worked with virtual robots. This is changing. Writing in the Scientific American, Bill Gates predicted “robots will be the next hot field” (Gates 2006). Certainly, this rise in popularity has started to appear in education. Consequently a review of the intellectual and practical basis relating to our use of educational robots becomes urgent. This paper is the result of that review. We propose that ten **E**ducational **R**obotics **A**pplications (ERA) Principles summarise the value of robots and robotic activities in any educational context.

We start by making a set of simple claims why we think these Principles are of value. We follow this with a description that references some of the supporting evidence and conceptual grounding. In order to provide some degree of ‘future proofing’ and to make the postulates independent of the type of robot, we have kept the descriptions as abstract as possible. Where contextual instances help to clarify our meaning we have used examples.

Although we call these Principles we are aware of their hypothetical nature. Over the coming years we expect research activity will gradually confirm, change, delete or find evidence that will steadily transform the postulates into verified principles. We finish the paper with a brief introduction to the e-Robot project which aims to accomplish this validation process.

Introducing the ERA Principles

The Principles are not stringently independent ideas. They form a holistic set of values that integrate in different combinations. For example Personalisation Engagement and Equity share an affinity. Personalisation also resonates with the Practical, Curriculum and Assessment, and the Pedagogical Principles.

The use of robots involves the interaction of students, teachers and technology. We have grouped the Principles under these headings more to assist their recall than an exacting effort of categorisation.

Technology	
1	Intelligence
2	Interaction
3	Embodiment
Student	
4	Engagement
5	Sustainable Learning
6	Personalisation
Teacher	
7	Pedagogy
8	Curriculum and Assessment
9	Equity
10	Practical

Table 1 The ERA Principles

Why the ERA Principles?

The Principles present a framework that:

1. Explains:
    a. How robots help students learn
    b. The benefits of educational robots to teachers
2. Offers a check list for those who want to:
    a. Design educational robots
    b. Develop activities that use educational robots
3. Helps justify the investment by schools in robotic technology
4. Suggests underlying cognitive and developmental processes
5. Provides researchers with a set of claims to evaluate

Intelligence

> *Educational Robots can have a range of intelligent behaviours that enables them to effectively participate in educational activities.*

An exploration of this principle needs to explain what we mean by:

1. Intelligent behaviour
2. Effective participation

For our purpose we recognise intelligence as belonging to a spectrum of behaviours focused on intentional goals (Sternberg 1985, Stonier 1997, Freeman 2000, Sternberg et al 2008). This means the robot need only possess task specific intelligence, which targets explicit learning objectives, rather than a general ability to act in unstructured situations. In this sense educational robots need to help students acquire specific knowledge, provoke them into thinking, help to develop skills or provide them with experience of situations and knowledge structures that mirror useful thinking patterns. They provide students with opportunities to use their knowledge in problem solving and engage in knowledge transfer, generalise concepts and develop their social skills.

Currently deep-down in their microchips, educational robots are based on what Winograd and Flores termed Western rationalistic tradition (Winograd and Flores 1986). These represent powerful thinking patterns capable of supporting many useful educational applications. Logo is an example. When a version of it is internalised into a robot's core behaviour it dictates what the robot can and cannot do. As technology and our understanding of educational robotics develop we expect to find new "core" behaviours capable of supporting different learning experiences.

Effectiveness contains the notion of efficiency, which we take to mean improvement. That is, students grasp ideas faster; get a better understanding of concepts, etc. This is relative. We grasp the idea faster than if we used some other method. It depends on which student and which method and what works well for one student may not work so well with another. Effectiveness also depends on the skill and experience of the teacher. Teachers teach: the technology is a tool to help – not replace them. Not every teacher will exhibit the same aptitude for using educational robots, irrespective of their general teaching skill. Whereas an adept, well trained teacher will achieve brilliant results, a robot will not make up for teaching deficiencies.

Generally, the measure of effectiveness is statistical. In most applications, with most students and most teachers, we expect intelligent robots will enhance educational achievement. If a robot does this for just one student it is valuable. The need for the statistical verification is economic: it is hard to justify the cost of a robot system for singular teaching successes.

Interaction

> *Students are active learners whose multimodal interactions with educational robots take place via a variety of appropriate semiotic systems.*

Working with robots is an active learning process, which is generally more effective because it is multi-modal. Interaction always involves the use of a semiotic system. Semiotics is usually defined as the science of signs (Halliday 1978). Crystal (1999) offers a more appropriate definition, which captures the heart of any educational enterprise:

> *Semiotics: The study of signs and their use, focussing on the mechanisms and patterns of human communication and on the nature and acquisition of knowledge.*

Signs evoke meaning through culture and context. For example in the West the colour red implies danger whereas in China it means good luck. However, the "value" (meaning) of the sign changes according to its use. So for example a red cross suggests medical help. Education is about learning the signs and signifying practices of our culture.

Logo is a semiotic system. We communicate our ideas to a robot by manipulating Logo symbols (commands) according to rules (programming syntax). The robot provides feedback through its movement – a sort of mechanical "body language". We can use this "body language" schema to understand other semiotic systems. For example if we place a robot on a number line and make it move by manipulating symbols (numbers and operation signs) using the rules (addition, subtraction, multiplication and division) students can explore the semiotic systems of numbers and arithmetic. Consider the equation (+4) – (-3) = (+7). Students are normally taught to solve this problem by remembering a meaningless rule like two minuses are a plus. Using the robots students use their visual, kinaesthetic and spatial modalities to develop mental models of negative number arithmetic. Importantly, they learn through understanding (NCTM, 2000 and Bransford, et al 2000). They see that on the number line to get the robot from (-3) to (+4), the robot has to travel (+7). This emphasises the meaning of the number system, particularly the relationships between positive and negative integers and the idea of subtraction as "difference".

Up until now robots have been dumbstruck[1]. Yet, natural language is humanity's major semiotic communication system. Valiant's new Roamer is changing that. The basic robot has a very powerful speech capability. This opens up many tantalising possibilities. For example by incorporating Logo's list processing ability, we can explore embedding in the robot the language ideas explored by Golenberg and Feurzeig (1987). In Incy Wincy Spider, an Early Years comprehension activity (Valiant 2009), Roamer sings out the verses of a nursery rhyme. The students realise the robot has "got it wrong" and their task is to teach it to get the verses in the right order. They do this by pressing the keys representing the "action" of the rhyme.

The Incy Wincy activity involves sequencing, a precursor to programming, which has been the primary way we interact with educational robots. If we transform the phrase "human communication" used in Crystal's definition of semiotics to the more apposite "Human Computer Interface" (HCI) and Human Robot Interface (HRI) we open exciting new possibilities. Forerunners of this technology are already finding their way into toys (Bartneck and Okada, 2001). And the work of some researchers on sociable robots (Brazeal 2004, Dautenhahn 2007) shows the possibility of very natural interactions between student and machine. For example AnthroTronix used Roamer as a basis for their Cosmobot robot. They have developed an interactive glove through which children can operate the robot through American Sign Language. The Principle also embraces the idea of tangible computing, which involves students purposeful construction of environments that control the behaviour of the robot.

How can this assist education? Vygotsky's concept of "tools" is a fertile starting point. The influential Russian psychologist proposed that just as we used tools to impact our external environment we need tools to modify our behaviour. Semiotics was the foundation of these 'mental tools' by which Vygotsky meant language (Wertsch 1985). Clearly robots represent physical tools which Papert, borrowing ideas from Winnicot (1971), called "transitional objects" or "objects to think with" (Papert 1980). Activity Theory (Leontiev 1978, Davydov and Radzikhovskii 1985, Engeström 1987, 1999) grew out of Vygotsky's work. This theory orientates us to a world of objects and our mental interactions with them. Some work on this has been done in relationship to Activity Theory and HCI (Nardi 1996). It is our contention that extending this work into educational robotics will provide a deeper understanding and offer new perspectives on the Interactive Principle.

Logo Turtle robots formed the prototype educational robot system. Logo offered new ways for students to develop mathematical, computational, geometric and scientific skills (Cuoco 1990, Kyngos 1992). From the initial conception of Logo (Feurzeig, et. al. 1967) to the existence of effective educational applications took many years and a great deal of research (Papert et. al. 1971 to 1981). As new robotic and HCI/HRI technologies emerge they will need to undergo the same process, but gradually we will see an increase in the capability of robots to support teachers and help provide valuable learning experiences.

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[1] The Tasman Turtle and some toys like Furby had limited speech capabilities.

Embodiment

> *Students learn by intentional and meaningful interactions with educational robots situated in the same space and time.*

We propose that by interacting with physical robots students can have positive educational experiences. And in a special caveat the claim extends to positive experiences that at a minimum are qualitatively different to those with virtual robots. While 30 years of practical work in schools has shown that thousands of teachers share this intuitive view, there is little hard data to verify the claim. Such evidence is contradictory, flimsy or does not target embodiment (Mills et al 1989, Gay 1989, Syn 1990, Weaver 1991, Mitchell 1992, Betts 1997, Adolphson 2005).

Our proposition does not critique the value of educational software. Instead, we aim to affirm the potential of physical robots. Our claim is built on a theoretical framework that has two strands:

1. Work by various authors in the areas of embodied cognition, AI and robotics
2. The original body syntonic claims of Seymour Papert (1980a)

Embodiment in cognitive science claims three things:

1. Mind has evolved, not as a machine, but as an integrated element of an organism embedded in a society and in a physical temporal world.
2. Mind and body are intimately intertwined. They form an ‘adaptive system’ – that works together to survive and thrive as their environment changes.
3. Most embodied cognitive processes are subconscious.

The concept of embodiment is rooted in biology (Muratana and Verela 1987). Despite this some writers have applied the term to software (Franklin 1997). Others argue that bodies are essential to cognition (Pfeifer and Scheier 1999). A survey (Ziemke 2001) looks at what kind of body is required. We restrict our meaning to living entities (students/teachers) and physical robots.

Embodiment is about how we engage with the world, extract and share meaning through our interaction with it and the objects it contains (Dourish, 2003). It is self evident that this applies to robots. But does it apply to virtual robots? It could; however, engagement is not with the “real world” and interaction is not with “real artefacts”. What appears on the screen is, at the very least, someone’s conceptual interpretation of the real world. Here we use the term real, in the way a thirsty man would view a real glass of water compared to a virtual glass of water.

Berthelot and Salin (1994) found that lack of experience with meso and macro space restricted elementary school students’ ability to cope with micro space[2]. We have seen students confused by the forward command moving a virtual turtle upwards on the computer screen. Going forward across the floor is the same for student and robot. This is the core of Papert’s body syntonic idea: students can ‘play turtle’. They can project themselves out of their ego centric mind, ‘stand in the shoes’ of the robot and directly perceive the world from its perspective.

Exploring the idea of embodiment could lead to new understandings about educational robots. Consider the proposal that maths is not an objective science, but that it arose out of the various ‘image schema’ derived from repetitive embodied experiences (Lakoff and Nunez 2001). These pre-linguistic entities provide a source for linguistic metaphors like ‘source – path – goal’, which sympathises with the attributes of mobile educational robots. Although this theory is controversial (Gold 2001, Madden 2001) many maths educators believe the work has merit (Schiralli and Sinclair 2003, Tall 2003). We believe that further research into embodiment will aide our understanding of educational robotics.

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[2] Micro Space is the space accessible without moving: things on your desk – the computer screen. Meso Space is on a room level and Macro is wide open spaces - something you journey through.

Engagement

> *Through engagement Educational Robots can foster affirmative emotional states and social relationships that promote the creation of positive learning attitudes and environments, which improves the quality and depth of a student's learning experience.*

In 1992 Classic Roamer debuted in America when a Chicago teacher tried it with a second grade student who normally never engaged in school work. He decided to make Roamer turn "all the way around". So he programmed it to turn 8, which made it turn 8 degrees. He was shocked at this small movement. He was also captivated and went on to experiment with 1, 2 and 3 digit numbers. He subconsciously gained experience of equivalency and after 45 minutes discovered 360 was the "magic number". Thirty years of ad hoc observations of students using robots has shown this is not an uncommon example of the Engagement Principle. Educational robots and their activities have a propensity for capturing students' attention.

Engagement is a far richer and apposite concept than the ubiquitous, "makes learning fun". For example work done at CNEFI[3] in Paris used Roamer to change the attitude of an adolescent who had been 'brain damaged' in an auto accident (Sarralié 2002). The student had lost the ability to do simple arithmetic. He was very aggressive towards the teachers trying to restore his competency. Eventually, they gave him a Roamer activity, which necessitated him performing basic calculations. The robot task captured his attention, helped him realise his incapacitation and made him amenable to working with the teachers. It is fair to say that fun was not a part of this experience, but engagement was very much in evidence.

While many children seem to possess a natural fascination for robots, this is simply an advantageous starting point. What Bruner (1966) called the "will to learn" is a factor in sustaining engagement. Teachers can motivate students, help develop interests and trigger their curiosity (Hidi and Renninger 2006, Keller 2000 and Arnone and Small 2010). We claim that educational robotics provide skilful teachers with many ways of achieving these conditions.

Engagement involves the relationship a student forms with the robot. The classic ideas on transitional objects (Winnicot 1971, Leslie 1987) all relate to the cognitive processes of young children. Recent work has shown that:

1. Our relationship with physical objects also involves emotional and social experiences
2. The experience is not restricted to young children
3. Robots fall into a new category between inanimate object and living thing

Sherry Turkle cites evidence of children talking about their experience with Sony's robot dog Aibo as if it was one of their toys, yet they interact with it as though it were a real puppy (Turkle et al 2006). She classifies robots as "relational artefacts" and splits them into Rorschach and evocative types. Like the Rorschach test, aka ink blot tests, Turkle shows that student responses to the robots mirror underlying issues in their life and reveal their strategies for dealing with their concerns. She describes the evocative aspect as philosophical: something that makes people think (Turkle 2007). Papert's famous anecdote about his childhood experience with gears is an example of an evocative object at work (Papert 1980b). Not in the cognitive sense that the young Papert acquired a mental model that years later would help him understand equations; it was the wider philosophical effect that inspired his extraordinary career.

Engagement is about capturing a student's attention. In our Chicago anecdote the student became absorbed in the turning problem. We mentioned his subconscious experience of equivalence, something the curriculum did not require him to learn for another two years. This is

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[3] CNEFI - Centre National d'Etude et de Formation pour l'Enfance inadaptée" (CNEFI) - National Centre of Study and Training for children with special needs)

an example of the “natural” learning of mathematics Papert so earnestly advocates. It is also an example of an intuition, which is an intrinsic element of the engagement principle.

No one taught the Chicago student equivalence. Yet he happily “unthinkingly” used these concepts. This is the crux of a definition of intuition: immediate apprehension by the mind without reasoning (Allen 1990). This definition gives intuition a disreputable reputation. Some psychological studies make no distinction between intuition and guessing (Myers 2002). Comparative philosopher Hope Fitz combines Eastern and Western traditions to offer an alternative view. She sees intuition as an integral process of the mind, which is grounded in sub conscious memories and experiences. While it is linked to reason, the act of insight does not involve reason (Fitz 2001).

Insights are not accidents. Our subconscious accounts for most of our mental activity (Bragg et al, 2008). It is through attention that we build and access our intuitive knowledge. Poincare (1905) described the process in terms of creative mathematics. He deliberately immersed himself in anything relating to a problem. He relied on his intuitive skills to channel insights into his conscious mind. Discussing this idea Papert (1978 and 1980) suggests this process is not restricted to a mathematical elite. We go further and speculate that is not restricted to mathematics. It empathises with the ideas of expert knowledge discussed by Bransford et al (2000), the psychological studies on implicit learning (Goschke 1997) and perhaps the more sensational and speculative assertions made by advocates of accelerated learning (Jensen 1995). Our claim is that through engagement in robot activities students develop their intuitive understandings.

Sustainable Learning

> *Educational Robots can enhance learning in the longer term through the development of meta-cognition, life skills and learner self-knowledge.*

School is not just a place for the acquisition of knowledge and skills. It plays an important part in the personal development of students. The English National Curriculum (2010) specifically states the need to help students acquire communication skills, the ability to work with other people, to present ideas and to be confident.

The way we use educational robots automatically engages students in situations where the opportunity exists to develop these skills. For example, the Robotic Performing Arts Project (Catlin 2010) illustrates an opportunity for students to develop their cognitive, social, personal and emotional skills in an authentic learning situation.

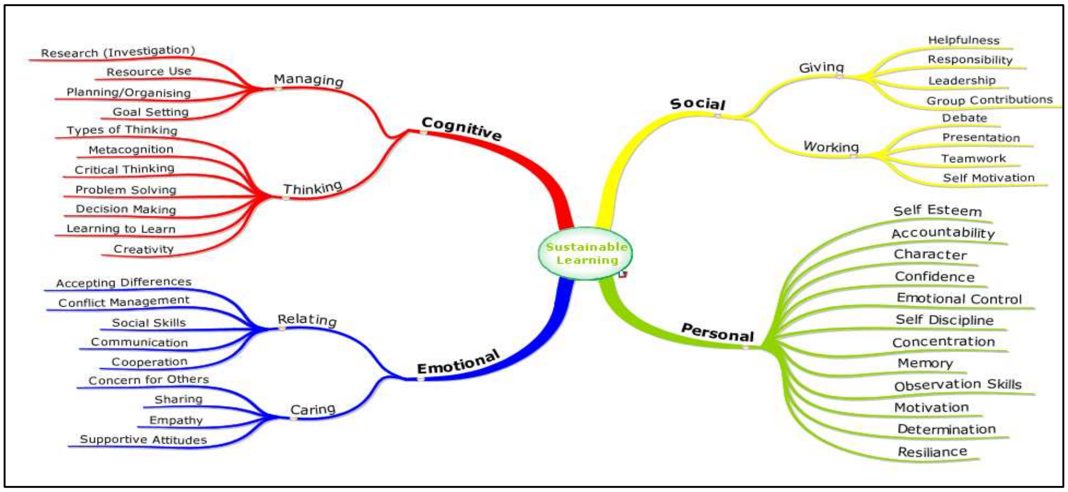

Figure 1: Mind map of typical sustainable learning criteria relevant to educational robots. - adapted from the Iowa 4H Program (2010).

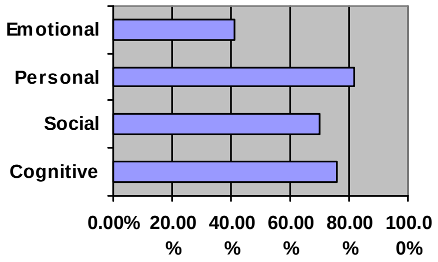

Figure 2 Involvement of sustainable criteria in a sample of 30 Classic Roamer activities.

Pedagogy

> *The science of learning underpins a wide range of methods available for using with appropriately designed educational robots to create effective learning scenarios.*

A central question in our project is what pedagogy justifies our belief that robots have a role in education? In the development of Logo, Papert synthesised ideas of Artificial Intelligence and the constructivist approach to education. That is, we understand the world by constructing mental models from our experiences. We assimilate or accommodate new experiences into our existing concepts or we accommodate them by modifying our existing ideas. Logo and Turtle robots provided experiences in a way that brought students into direct contact with some powerful and important ideas, particularly in mathematics.

Is this the only way we can or should view the educational process? We have already cited the potential insight we might gain from a review of Vygotsky and Activity Theory. While there are differences in these and other ideas, there are also many similarities. What clearly emerges is not some definitive truth about the way we learn but more of an orientation. This is starting to become known as the science of learning. Papert talks about the spirit of Logo and that life is not about “knowing the right answer”, but getting things to work. We need to adopt this pragmatic approach and let the science of learning inform and sometimes inspire our development of educational robots and their activities. Ultimately our judge of success is not whether we have a consistent developmental framework, but whether we can connect learning science and the technology with successful classroom practice.

Another aspect of pedagogy is a set of strategies that help us to create and analyse educational robotic activity. An analysis of work with Valiant’s Turtle and Classic Roamer has identified 28 different methods for using educational robots (Catlin 2010a).

Catalyst
Challenges
Conceptualisation
Cooperation
Creative
Curriculum
Deduction
Demonstration
Design
Engagement
Experimentation
Experience
Exploration
Focussed Task
Games
Group Tasks
Inductive Thinking
Links
Modelling
Memorisation
Pacifier
Presentations
Problem Solving
Projects
Provocateur
Puzzles
Relational Artefact
Transfer

Table 2: Pedagogical tools for educational robots

Most activities employ several strategies. For example a Roamer Activity called Robot Rally Race (Valiant 2009) starts with a challenge to find the fastest route, involves experimentation while the students try to find out how fast the robot travels over different terrains, and uses this statistical data in a focussed task to calculate the fastest way from start to finish. Table 2 is not a closed list. We expect to find other tools as the power of robots grows – for example Valiant's work on robotics and storytelling is likely to yield some new approaches.

Curriculum and Assessment

> *Educational Robots can facilitate teaching, learning and assessment in traditional curriculum areas by supporting good teaching practice.*

Most formal education takes place in schools. The "local" community decides what the students should learn and typically demand "proof" of achievement. While the curriculum and assessment methods vary between different communities there are many similarities. If educational robots are to make a significant impact they must be able to address the two items that concern teachers the most:

1. Teaching the curriculum
2. Assessment and testing

The Curriculum and Assessment Principle includes the phrase "good teaching practice". How does this affect how a teacher teaches? Does it alter their traditional role as a dispenser of knowledge and what do educational robots have to contribute to this situation? These questions lead us to consider and develop another of Vygotsky's innovative ideas: the Zone of Proximal Development (ZPD) defined as what the learner can do alone and what they can do with assistance (Vygotsky 1978). We predict the ZPD concept will develop to embrace technology in general and intelligent robots in particular. The characteristic of this model is that the teaching and learning experience will be more flexible than the Logo model of student teaching the robot or the teacher dispensing knowledge. It will be a dynamic model allowing any of the participants to be a teacher or a student.

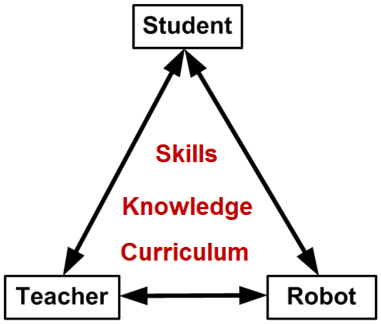

Figure 3: The dynamic relationship between teacher, student and robot shows that the learning and teaching interactions are bi-directional.

This proposition assumes that educational robots can be applied broadly across the curriculum. Turtle robots were tightly linked with mathematics and Roamer, Lego and other robots have made clear links with STEM (**S**cience, **T**echnology, **E**ngineering and **M**aths) subjects in general. However, it is clear that robots are not restricted to these domains. In 1992 Harrow schools in the UK ran a district wide robotic art project. Students had to make Roamer into animated sculptures of fantastic insects. Perhaps more surprisingly is the use of robots in the study of moral and social values (Bers and Urrea 2000). Currently Valiant is developing a library of between 200 and 300 free and commercially available Roamer K-12 activities in all subjects. Some of these, like the fantastic insects, are major projects; others like the Incy Wincy activity are completed in a lesson. The potential for activities far exceeds what a school could use in a balanced approach to teaching.

Formative assessment is a crucial part of effective learning environments particularly when it forms an unobtrusive element of an activity (Bransford et al 2000b, Black and Wiliam 2006). Feedback is embedded in robotic goal orientated action. Robots inherited this trait from Logo. Students propose an interim solution and then decide if it is satisfactory or whether they need to and/or how to make improvements. This makes formative assessment a natural part of this dynamic interactive process.

Personalisation

> *Educational robots personalise the learning experience to suit the individual needs of students across a range of subjects.*

Ellwood Cubberley, a contemporary of John Dewey and Dean of Education at Stanford urged we view schools as factories in which the children were raw products to be shaped and fashioned to meet the demands of twentieth-century civilisation (Cubberley 1916). His rhetoric got worse: *"the business of schools was to build its pupils according to specifications laid down"* and this required "*continuous measurement of production to see that it is according to specification, the elimination of waste…"* Contrast this with the educational aims stated in the UN Charter for the child. It charges nations with developing the child's personality, talents and mental and physical abilities to their fullest potential (United Nations 2001). Robots support the UN child centred vision.

Table 3 Ways educational robots support the Personalisation Principle

1.	Self Expression	Educational robots are tools that allow students to explore ideas and express their understanding in personal creative ways.
2.	Flexible Use	Robots are adaptable to the needs of the teaching situation (see Practical Principle) and the needs of the individual student.
3.	Differentiation	Robot activities find a natural level of difficulty. They support the constructionist principles and recognise that students build their own understandings in their own ways. They support struggling learners and challenge gifted students.
4.	Learning Styles	Robots engage in multiple modal experiences: • Kinaesthetic • Visual • Spatial • Auditory • Tactile

These ideas are familiar to constructionists and have drawn their fair share of criticism. Let's deal with some the most common. Students setting goals does not lead to lower standards or the study of irrelevant topics. While students make the choices, good constructionist teachers "rig the deck". They motivate and encourage students. In fact once ignited students' imagination usually outstrips the activity objectives and pushes beyond expectations. This is not about achieving par; it is about the excellence beyond that. In a Classic Roamer task the students had to make a robot dog. Suddenly it needed "a wagging tail". How to do this was far beyond the teacher's skill and knowledge level, but not beyond her teaching skills. The students found a solution - a rubber tube that wagged furiously as Roamer wiggled its bum!

Equity

> *Educational robots support principles of equity of age, gender, ability, race, ethnicity, culture, social class, life style and political status.*

Before we can understand how robots help with equity we need to understand some of the issues involved. Equity means giving students an equal chance for a good education. Or does it mean giving them a fair chance? It turns out that equity is very hard to define, and how you define it affects how you deal with it (Ainscow et al 2006). Equal chance for example could mean making sure that each school has the same level of funding, resources, quality of teaching, etc. A fair chance would perhaps look at compensating for disadvantages.

Society can only determine a curriculum culturally entailed in favour of the mainstream of the community. For anyone who belongs to a cultural group that is not part of the mainstream, and whose sub group would produce a different curriculum, they have to make more effort to achieve academic success. There are those who argue such a curriculum represents a lingua franca for a society (Hirsch 1988). If minority students want to fully participate in main stream culture, they need to overcome cultural barriers. Though in practice mainstream-culture eventually changes because of input from minority participants (Lave and Wenger 1991).

Inequity arises from things like unequal funding (Kozol 2005), lack of qualified teachers, high quality materials, equipment and laboratories (Darling-Hammond 2005), overcrowded classrooms (Ferguson 1991) and poor quality teachers (Dreeben 1987).

Research and classroom practice show that minority pupils perform better when teaching is filtered through their own cultural experiences and frames of reference (Gay 2000). We claim:

1. Robots are tools that allow students to express themselves from their cultural perspective
2. The creative nature of robot activities makes them amenable to cultural modification

Because most societies have a tradition of artificial life (Simons 1986), robots have the potential to be culturally acceptable. Most cultures have developed the art of puppets and many technically advanced cultures created automaton of various types. Robots are another manifestation of this tendency. The mechanisms behind robots as transitional and relational objects make robots potentially tools through which children can express themselves. In a study of Huli children in Papua New Guinea, anthropologist Laurence Goldman (1998) concluded:

> In their “as-if vignettes”, pretenders are constructing, experiencing and implementing their models of the world, models that are always culturally encumbered and inflected.

This is the same mechanism Valiant has observed with students of indigenous cultures like the Maori, Australian Aborigines and some Native American peoples using Roamer. Students project their imagination into artefacts. With robots these imaginations come to life and enable students to express themselves in a way that reflects their heritage and situatedness in the modern world. They can connect their heritage with technology in their terms.

A robot teacher recently appeared in a Japanese school (Demetriou 2009). Saya, a humanoid invention of Professor Hiroshi Kobayashi, took the class register. Work at Carnegie Mellon with the robot Asimo is exploring and perfecting a robot that can read to students (Mutlu et. al. 2006). At a cost of $1M Asimo is a long way from classrooms, but it does imply that technology can “make up” for the poor quality of teachers. This argument is already well advanced with cognitive tutors (Woolf et al 2001, Koedinger, 2001). We do not subscribe to this view. Some very early research showed that technology together with teachers working with students got better results than students learning with teachers or technology alone (Dalton and Hannafin, 1988). This is very old research, but we suspect it still has validity. We believe that as robots become more adaptive and capable of providing sustained, uninterrupted interactions with the students, the teachers will be able to concentrate on working in ways that have greater impact on a student’s learning. This demands higher teaching skills not lower. It helps make teachers more effective.

Practical

> *Educational robots must meet the practical issues involved in organising and delivering education in both formal and informal learning situations.*

We often see approaches to education produce spectacular results in research or other controlled circumstances, followed by limited success or even outright roll-out failure. While we believe robots and ERA compliant activities will make a positive educational contribution, careful implementation and management is necessary if a school is to take full advantage of what robots offer. The Practical Principle considers this on two levels:

1. Systemic Implementation
2. Classroom Practicality

The Classic Roamer had a 95% penetration of UK Primary schools. This does not mean schools are getting the most out of them or using them regularly. Taking care of systemic changes issues will help people get the most out of robots. The following comments apply at the level of classroom, school, school district or even whole country.

Table 4 Elements of change adapted from Thousand and Villa (1995)

Vision	+	Buy In	+	Skills	+	Resources	+	Plan	=	Change
	+	Buy In	+	Skills	+	Resources	+	Plan	=	Confusion
Vision	+		+	Skills	+	Resources	+	Plan	=	Resistance
Vision	+	Buy In	+		+	Resources	+	Plan	=	Fear
Vision	+	Buy In	+	Skills	+		+	Plan	=	Frustration
Vision	+	Buy In	+	Skills	+	Resources	+		=	Vacillation

Table 4: Summarises the elements required to make systemic change and what happens when an element is missing. Schools or districts wishing to integrate robots into delivering the curriculum need to address each of these issues. We propose the ERA Principles will help people develop an understanding and vision of how robots can be used.

At the moment most people think school robotics means students building robots. This type of activity is in fact a subset of the more general use of robots. Most teachers would not deem it practical to have to build the robot to engage in the Chicago Activity. For teachers to buy-in to using robots they must perceive their value outweighs the effort in dealing with the logistics and the preparation process. We are not trying to imply that there should be no applications that involve engaging in technical activity, but there needs to be activities that can be "ready to go in minutes" and do not require technical expertise. This does not mean the robots need to be crude. You do not need to be technically savvy to use sophisticated technology like a TV.

1 Individual work
2 Group work
3 Whole class learning
4 Home schooling
5 Learning support
6 Gifted programmes
7 SEN Interventions
8 Project work
9 Play
10 Games
11 Competitions
12 Collaborations

Table 5: One aspect of a robot's practicality is its ability to be used in many different teaching scenarios.

We do not feel that robotics will receive the kind of investment in skill training that has been expended on ICT (technology). Therefore it is essential that training is in-built into the activities: a sort of just-in-time and on-the-job approach. This was not feasible a few years ago but with the advances in online training and quality of open source platforms like Moodle it is now possible. Where teachers do go on training courses, online systems will act as support when they return to the hubbub of the classroom.

Budgets are always tight in schools – particularly if the school does not have a "vision". However, it can help if robots integrate with equipment schools already have.

So many times we have seen robot projects, particularly events like out of school competitions, generate huge amounts of enthusiasm. When the students go back to school that energy dissipates into the mundane. With proper planning teachers can use these events to boost the student's interest in regular lessons. Pupils cannot learn from using a robot alone. It is one element in a complex process. Well planned use of robots will ensure that the student has an opportunity to link their robotic experiences with formal aspects of the curriculum.

Conclusions

The ERA Principles represent the issues surrounding educational robotics. While this paper presents a quick survey of some of the pertinent arguments and hints at some of the evidence, it is clear that a lot of research is necessary to advance the subject. For many the research strictures dictated by NCLB's[4] positivistic approach to research is nonsense. However, there was a point to it. Many whims have been perpetuated onto schools. Our disagreement with NCLB lies with the rejection of the normative and interpretative research methodologies (Cohen

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[4] No Child Left Behind – President Bush's view on education which insisted that schools only used researched supported teaching methods.

and Mannion 1994). Perhaps this is not surprising because many of these techniques are ideal for studying the use of robots in schools. We also believe that what passes for longitudinal research is too short term. A three year research program would have missed the effects of Papert's gear experience. It is our intention to set up the e-Robot project which will aim to gather research information from an online community. The aim of this is to start to gather and collate the research necessary to develop the ERA Principles.

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