# A Day in the Life of an Educational Robot

## *A Report and Analysis of a School Working with Educational Robots*

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***Abstract*—Educational robots are powerful tools with the potential to make regular contributions to the educational life of a school. For robots to fulfill this role they need integrating into everyday teaching practice. This paper is the first in a series that looks at that process in a specific school. It reports a first encounter of pupils with Roamer robots as part of a week long project and highlights some assimilation issues. The Educational Robotic Application (ERA) Principles is used as an evaluation framework and to provide data for the e-Robot project, a long term programme aimed validating the ERA Principles.**

***Keywords*—Teaching with Robots, TWR, Roamer, Educational Robot, ERA Principles, e-Robot, Valiant Technology**

### I. Introduction

This report is the first in a series aimed at discovering what happens to robots when they go to school. What does it take for a school to embrace the potential of the robots to enrich the educational experience of the students on a regular basis? It is part of a wider project that is interested in discovering strategies that will ensure that the technology is successful as well as the nature of potential pitfalls and how these may be avoided.

The report looks at data accumulated by Valiant Technology over the last 30 years. This presents an interesting perspective on the conditions that may deter the long term use of the technology. The plan is to monitor adoption of the technology at a single school, Maple Cross Junior Middle and Infant school in Rickmansworth, England. Therefore, the report presents baseline data about the school gathered from public records supplemented by interviews with various staff members. The school conducted a week long ICT/English/DT[1] project in which they planned to use newly acquired Roamer robots. Observations were gathered through unstructured observation by two non participating onlookers and supplemented by interviews with participating teachers and a review of the comments made by students.

### II. The Project, ERA and e-Robot

The data is analysed using the Educational Robotic Application (ERA) Principles, which provides a framework for evaluating the effectiveness of educational robotics [1]. This is done as part of the e-Robot project, a longitudinal research programme aimed at gathering evidence to verify, modify or refute ERA [2].

According to ERA Pedagogy Principle, the Maple Cross activity is classified as a "Project"[2]. Generally, Projects are unique. How do we extract meaningful data from such one-off events? How can we compare the results gathered with other work? The premise is the ERA Principles summarise the value of educational robots. Any educational robot activity that delivers results that correlate well against these principles:

- Demonstrates the positive educational value of the specific activity - even unique projects like this
- Helps substantiate the principles as a true summary of the educational value of educational robots

The aim of the e-Robot project is to gather data from many different activities using ERA as an analytical tool. The more activities affirm ERA (or modify it) the more we are able to use this tool with confidence.

This process is in its infancy. In fact only one formal presentation of ERA Analysis has ever been published [3]. The efforts here should be perceived as fledgling exploration of gathering and analysing ERA data. Increasing mastery and competence will eventually lead to a substantial growth in the e-Robot database.

### III. Commercial Perspective

Valiant Technology have sold Turtle type robots to schools for 30 years. Data from the company's customer support and sales enquiry desk provide an interesting perspective on the fate of several hundred thousand robots. Virtually, 100% of British Infant and Primary schools possess educational robots. An estimated 90% of these own a Classic Roamer, similarly 90% have Beebots and about 10 to 15% have Pip or Pixies. Around 12% purchased Valiant Turtles[3]. It is estimated that about after five years two thirds of these robots spend most of their time in the cupboard and are rarely and sometimes never

[1] ICT - Information Communications Technology and DT - Design Technology.

[2] See Section 4 in B. ERA Analysis below.

[3] BeeBot http://www.kenttrustweb.org.uk/kentict/kentict_ct_bee.cfm
Pixie and Pip http://www.swallow.co.uk/
The Valiant Turtle
http://roamerrobot.tumblr.com/post/23079345849/the-history-of-turtle-robots

used in the classroom. Table 1 shows a number explanations for this state of affairs.

TABLE I. WHY SCHOOLS STOP USING ROBOTS

| ***Reason*** | ***Explanation*** |
|---|---|
| Motivation | The school purchased the product for the wrong reasons.<br>a) Schools purchased the product because they felt it would get them a better Ofsted Report[4], there was no real motivation or strategy to use the robots.<br>b) Schools needing urgent repairs to robots because they "planned the use of the robot next semester." This usually means the school is focussed on the technology not how the robots can help students understand difficult concepts - which is usually occurs throughout the academic year. |
| Staff Movement | The teacher who motivated the purchase and used the robot moved schools and the other staff had never used it. |
| Poor Training | The teachers do not really know how to use it beyond a few traditional Turtle type activities. |
| Fading Intrest | People focussed on the technology and not effective applications, after a while some new "gizmo" captures their attention and they move their focus. This does not mean that the older technology stops being effective, it simply loses its novelty value. |

There is a flip side to this. There are schools that have been using the technology on a regular basis for one, two, even three decades. These schools have managed to fully embrace the technology. An ad hoc survey of these schools reveals that schools who use the technology regularly have one or more of the following:

- Teaching staff who who use the technology and have been in post for a number of years
- More than one teacher uses the technology
- An approach to teaching that is energetic and generally compatible with constructionvist teaching methods
- Personal, positive experience of the effect of using the technology with students
- A creative vision on how to use the technology to support the teaching of the curriculum
- A supportive school environment to this general approach

## IV. MAPLE CROSS JMI

Maple Cross is a small village of about 2,000 people situated just inside London's orbital Motorway. It is essentially a working class area on the borders of Greater London [4].

*Maple Cross Junior Mixed Infant and Nursery School is well below average in size for a school of its type. It has an above-average proportion of girls. A large majority of pupils are of White British origin and the proportion of pupils from minority ethnic groups is average. However, the proportion of pupils who speak English as an additional language is below average. The proportion of pupils known to be eligible for free school meals is above average The proportion of pupils with special educational needs and/or disabilities is above average[5]. Since the last inspection the number of pupils at the school has increased significantly* [5].

Tables II, III and IV present the government data relating to the school and its performance.

TABLE II. SCHOOL CHARACTERISTICS

| ***Characteristic*** | | ***Maple Cross*** | ***National*** |
|---|---|---|---|
| Enrollment | Boys | 69 | |
| | Girls | 82 | |
| | Total | 151 | |
| % With SEN[a] Statements | | 7.3 | 7.9 |
| % Pupils with English as a 2nd Language | | 10.8 | 17.5 |
| % Pupils Eligible for FSM[b] | | 29.5 | 19.3 |

a. a SEN - Special Educational Need

b. FSM- Free School Meals

c.

*The link between FSM eligibility and underachievement is very strong and data on FSM is easily collected and updated annually* [6].

TABLE III. OFSTED REPORTS

| **Summary Ofsted Reports: Grades - 1 Outstanding, 2 Good, 3 Satisfactory [c] and 4 Unsatisfactory** | | | |
|---|---|---|---|
| ***Criteria*** | ***2006*** | ***2009*** | ***2011*** |
| How well do learners achieve? | 3 | 3 | 2 |
| The standards reached by learners | 3 | 3 | 3 |
| How well learners make progress, taking account of any significant variations between groups of learners | 3 | 3 | 2 |
| How well learners with learning difficulties and disabilities make progress | 3 | 2 | 2 |

d. The term satisfactory is a misnomer. It indicates a poor school which requires to take energetic action and will be subject to extra monitoring.

Clearly Maple Cross deals with difficulties typical of impoverished communities. They are making admirable progress. Will the regular use of Roamer help to support and enrich this effort?

At the end of the academic year the deputy head will be promoted to head teacher and the ICT Coordinator who invested in the robot will also leave. Will this trigger the type of issues listed in Table II?

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4 Schools in England are regularly inspected by the Office for Standards in Education (Ofsted). Ofsted reports are public domain and make statements on the performance of the school and recommendations for improvement. Poor Ofsted reports lead to parents sending their children to other schools and even dramatic action including the dismissal of staff. Since the use of Educational Robots (programmable toys) have been enshrined in the National Curriculum since 1998 Ofsted would view their absence in a school as a demerit.

5 This seems to contradict the Department of Education Data in Table II.

TABLE IV. NATIONAL TEST RESULTS

| KS1 (5 - 7 years old) comparison with all schools | | | | |
|---|---|---|---|---|
| ***Quintile*** | ***English*** | ***Reading*** | ***Writing*** | ***Maths*** |
| Highest | | | | |
| 2nd Quintile | | | | |
| 3rd Quintile | | | | |
| 4th Quintile | | | | |
| Lowest | | | | |
| **KS2 (7 - 11 years old) comparison with all schools** | | | | |
| ***Quintile*** | ***English*** | ***Reading*** | ***Writing*** | ***Maths*** |
| Highest | | | | |
| 2nd Quintile | | | | |
| 3rd Quintile | | | | |
| 4th Quintile | | | | |
| Lowest | | | | |
| **KS2 progress comparison with similar schools** | | | | |
| ***Quintile*** | ***English*** | ***Reading*** | ***Writing*** | ***Maths*** |
| Highest | | | | |
| 2nd Quintile | | | | |
| 3rd Quintile | | | | |
| 4th Quintile | | | | |
| Lowest | | | | |
| **KS2 progress comparison** | | | | |
| | ***All Schools*** | | ***Similar Schools*** | |
| ***Quintile*** | ***English*** | ***Maths*** | ***English*** | ***Maths*** |
| Highest | | | | |
| 2nd Quintile | | | | |
| 3rd Quintile | | | | |
| 4th Quintile | | | | |
| Lowest | | | | |

e. Similar schools are those where the students started the Key Stage with the same attainment level

## V. ROBOTS IN MAPLE CROSS SCHOOL

The school has 2 Classic Roamers and a set of Beebots when they decided to purchase a set of 5 Roamers. This new purchase inspired ICT Coordinator Nick Flint to initiate a school project.

## VI. THE PROJECT

The following was the initial project concept:

*This project is part of our joint ICT/Design Technology (DT) week. For the DT element - the rest of the school will be making musical instruments out of junk, but my year 5/6 class thought that sounded 'boring!' So - the compromise we have made is that on Monday they will be making 'musical buildings', and I envisage them using the Roamers to navigate through the buildings.*

*There will be a link to literacy at some stage in the week. Primarily, I would like them to write out pseudo code for the instructions they give their Roamer. I would then like them to build on this code to write a short story using instructional language, based on their code. I should also add that their theme for the term has been Star Wars, so a nod to the genre would be useful.*

Nick Flint

This evolved into the idea of using the Roamer music capability to mimic R2D2 type communication. Various unavoidable non-teaching disruptions took place, which upset the general plan.

The students constructed a "Star Wars" City (Fig 1) out of junk material. This was intended as a backdrop for the Roamer stories.

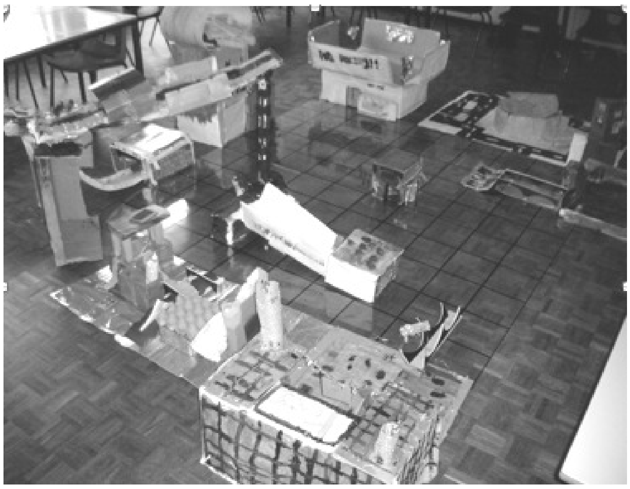

**Figure 1 The Star Wars Cityscape created as part of the project**

This seemed as much an art and crafts as a DT Project. The city was impressive and clearly the students had explored a range of materials, textures, fastening methods, shapes and forms.

The students completed a various writing assignment, which the teacher described as fabulous. They had to compose a persuasive piece of writing for Vader & Son Estate Agents. It was written in the style of housing particulars. Some clever, humorous examples of work appeared on the school blog.

### A. *Using the Robot*

Because of the disruptions, they were not able to use the robots until the last day. The day started with students sharing their story ideas with members of their group, then deciding what plot to develop. In the end, there were two groups with stories involving two robot characters and a single group with a story based on a Roamer and a human character. This process took about 30 minutes.

They then started to learn how to program the robots. This process consisted of them working in small groups listening to instructions from the teacher, experimenting and listening to the Roamer's help files which told them how to correct their programming errors (Fig 2).

**Figure 2 One of the groups engaged in experimenting with Roamer Programming.**

The students then developed their stories writing out a narrative using words like '*went forward to the bar, turned to meet each other, beeped at each other before…'* The pupils then programmed the enactment of their stories, tested and debugged the programs.

The Star Wars City had been moved from the classroom to the school hall. Each team took turns to go on set and film their story. Meanwhile the other groups stayed in the classroom and carried on experimenting with the programming capabilities of the Roamer.

The 3 stories produced and enacted by the students were:

- **We Don't Serve Your Kind Here**: A version of a scene from Star Wars where the robots are refused entry into a bar
- **Good Versus Evil**: the robot meeting with Darth Vader
- **Eastenders**: A romance story based on the BBC TV Soap Opera

## VII. ERA Analysis

In this section each ERA Principle will stated and then collated to the observations of the Star Wars Project

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

The students used a Standard Primary Roamer. This gave them the capability of working with movement, wait, speed, music and volume. Even though they were beginners who had had only 30 minutes of experience with the robot, they used all of these features. They did not use the repeat and procedure functions and could not use the robots extended speech capability or its control features (inputs and outputs).

Bransford et. al. claimed that students' ability to benefit educationally from programming was restricted by their knowledge of the programming language [7]. Clearly, the basic programming capacity of the robot was easily learnt. The resulting dramas were limited, but this was more a matter of the time spent on the task, than the potential of the robots to provide the students with valuable experiences.

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

The traditional Turtle type robot semiotic systems were in play in this activity: the symbols used to programme the Roamer and visual response of the students to the robots movement in space. This clearly connected students to various mathematical ideas (see the Curriculum and Assessment Principle).

The semiotic of the Star Wars story was also present in the activity. Two of the three groups responded to this. The third did not. (see Conclusions for further discussion of this point).

***3) Embodiment:*** *Students learn by intentional and meaningful interactions with educational robots situated in the same space and time.*

This is always the critical question with robot activities - why a physical robot - could we do this with a virtual robot?

As reported in the initial ERA Paper [1], all the adults involved in this project believed that the robot was offering a unique experience that would not be the same on screen. Moreover, they all felt that this experience was valuable. However, they all found it difficult to provide a concrete explanation of why they found this so.

Body syntonic activity was observed on several occasions [8]. This was spontaneous. Students got up and walked through the robots movements, using their bodies to solve the problems.

Another aspect of embodiment was observed, which has been noticed before, but not recognised as an aspect of embodiment deriving from work with physical robots. This is the animation of the students as the robot acts out their instructions. Their physical response was often lively and indicates a connection to the outcome (Fig 3).

An interesting observation is student reaction to mistakes. It almost universally, humorous. It is not their mistake. The blame is projected onto the robot. It got it wrong. Even when the mistake is revealed publically, the atmosphere is more like a TV Outtake Programme; the audience share the joviality and spare the student from what is normally a humiliation.

Papert [9] claimed the debugging process was a positive way of discovering mistakes. Indeed it forms an iterative process of "getting the right result". However, what has never been noted is the student reaction to success. In all these activities, students demonstrated their success. In particular, the Eastender's team danced in celebration. This is another indication of their physical connection to the challenges and their outcome.

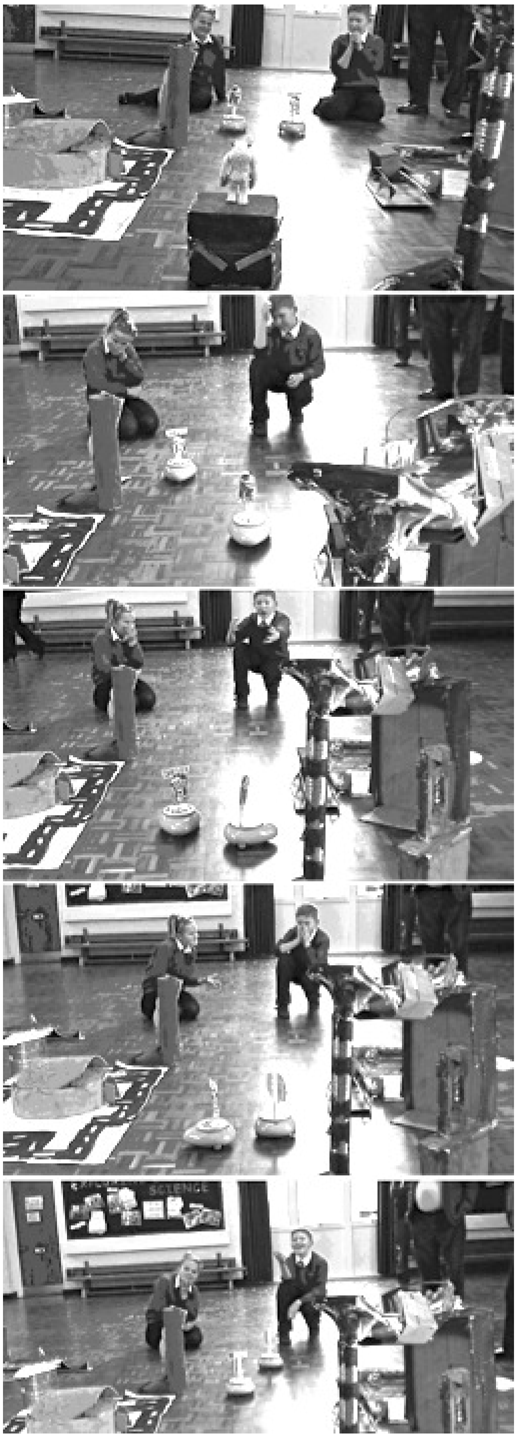

**Figure 3 Student animation as the robot acts out its program indicates embodiment in action.**

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

This principle is about understanding the structure of the activity. Twenty-eight different methods have been identified as ways of using the robot. Most activities involve more than one. Table V describes the methods used in this project.

TABLE V. MAIN PEDAGOGICAL ELEMENTS OF THE PROJECT

| | Pedagogy | Description |
|---|---|---|
| 1 | Project | Projects are spread over several lessons. The robot cotributes to the project outcome. This can be a major or a minor role. |
| 2 | Cooperation | The way the robot day was set up required students first in small and then larger groups. |
| 3 | Creative | The project involved creative opportunities in the creation of the sets and in writing opportunities and the plotting of the drama. |
| 4 | Experimentation | The students experimented in learning how to program the Roamer. |
| 5 | Group Task | It was a group based activity. |
| 6 | Presentation | The outcome of the project was a video presentation of their story. |

***5) Curriculum and Assessment****: Educational Robots can facilitate teaching, learning and assessment in traditional curriculum areas by supporting good teaching practice.*

The project as stated in Section V stated the curriculum areas of interest were:

- Design Technology
- Information and Communication Technologies
- Writing
- Music

Specific objectives were not stated, except the notion of using pseudo code in the writing of the robot dramas. The outcome of design technology work was impressive, although a little more Art than Design Technology. This is not untypical of Primary school approaches to that subject.

However, the work did not involve resistant materials or tool skills associated with these materials. This is not untypical of Primary schools in general.

The ICT effort was dominated by learning to program the Roamer. Some high quality writing had been done earlier in the week, but the standard dropped when it came to using the Roamer. This was understandable given the general circumstances.

The discovery of the robot music facility and the volume feature did attract experimentation with musical notes as the students tried to make the robots sound like R2D2.

There was little formal assessment done, except, of course, the student movies. Though as an example of writing they were simple, as an expression of ICT they represented good work.

There was a plenary session and the students universally cited the development of their programming skills as their main achievement during the day. Clearly their curiosity was provoked because they eagerly asked questions about other keyboard functions that they had not had tome to explore.

***6) 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 the preliminary work students worked well and stayed on task. However, when the robots came out, engagement, enthusiasm and energy noticeably increased (Fig 4).

**Figure 4 All eyes on the Roamer. The concentration dramatically increased when the robots were used.**

The teams took it in turns to do the filming. When they had completed the task they returned to the classroom and voluntarily continued to explore and play with the robots.

Interestingly, in the plenary session several of them enquired whether they could buy them and take them home. This indicated an aspect of engagement - enjoyment.

The Roamer day ended the school closed for the two week Easter holidays. On returning from this break students were set a writing assignment about the project. It is clear from the student work that the enthusiastic element of engagement was still evident [10]. One student, who was not there on the day, but still had to do the writing assignment reported:

*Everyone says that they had loads of fun and that everyone was drawn in from what the people said. From the sounds of it I think everyone had a really good time. I wish I could have been there.*

This was the "word in the playground"; inhibited by the desire to provide the answer the teacher wants to hear.

Nick Flint reported:

*Roamer provided motivation and a focus. A couple of students went on the school blog during the Easter break and wrote about the session. This is the first time they have ever done anything like that, and to do it in the holiday was even more remarkable.*

This certainly supports the engagement claim that work with educational robots improve the attitude of learners about learning.

***7) Personalisation:*** *Educational robots personalise the learning experience to suit the individual needs of students across a range of subjects.*

The class was reasonably homogenous and special changes to the robot, or the activity were not necessary. Consequently, the Personalisation Principle was not featured.

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

The class of 20 consisted of 15 girls and 5 boys. They worked together well. The ICT Coordinator/class teacher, pointed out that the group who did the romance (Eastenders) story line were all girls. It is an aspect of equity that the robots are tools which allow students to express their interests and concerns. It was also noted that particularly engaged in the tasks was a pupil from a traveler family/background.

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

Sustainable Learning skills are also referred to Life Long Learning skills. The essence of this idea is engagement in this activity offers the student the opportunity practice and develop skills that can be applied to radically different situations.

The activity engaged students in practice of sustainable learning skills. Table VI lists the skills identified by ERA and highlights those involved in this particular activity.

The highlighted skills were observed. This does not mean that the other skills were not involved or being developed. Nor does it mean that all students were developing the skills in the same way or to the same level. In fact an incident occurred where a student did lose emotional control. This is a recognised problem with this particular student and was dealt with according to school policy. Robot develop the sustainable skills by putting students into situations where they have the opportunity to practice those skills. We all fall over when we learn to walk. But generally, this is done in a safe environment. There is always the chance that problems will occur in the dynamic situations Roamer activities create. While it safe environment, it also is an area deserving of more detailed research and development to find positive ways of dealing with such breakdowns.

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

The way the activity was conducted and the circumstances that prevailed infringed this important Principle. This does not reflect the professionalism of the teaching staff, nor the particular activity.

It was a general view of the teaching staff and the observers that too much was being attempted in such a short time period. The day was a success, but it was possible to improve the quality of the planning and execution in a way that would allow the students to get more out of the activity.

TABLE VI. SUSTAINABLE SKILLS ANALYSIS

| Category | Sub Category | Sustainable Skill |
|---|---|---|
| Cognitive | Managing | Research (Investigation) |
| | | Resource Use |
| | | Planning/Organisation |
| | | Goal Setting |
| | Thinking | Types of thinking |
| | | Metacognition |
| | | Critical Thinking |
| | | Problem Solving |
| | | Decision Making |
| | | Learning to Learn |
| | | Creativity |
| Emotional | Relating | Accepting Difference |
| | | Conflict Management |
| | | Social Skills |
| | | Communications |
| | | Cooperation |
| | Caring | Concern for Others |
| | | Sharing |
| | | Empathy |
| | | Supportive Attitudes |
| Social | Giving | Helpfulness |
| | | Responsibility |
| | | Leadership |
| | | Group Contributions |
| | Working | Debate |
| | | Presentation |
| | | Teamwork |
| | | Self Motivation |
| Personal | | Self Esteem |
| | | Accountability |
| | | Character |
| | | Confidence |
| | | Emotional Control |
| | | Self Discipline |
| | | Concentration |
| | | Memory |
| | | Observation Skills |
| | | Motivation |
| | | Determination |
| | | Reslience |

The prominence of the robot overpowered the project objectives. That is, the notion of the Star Wars theme faded into the background. In doing this, the potency of the overall project to deliver the original learning objectives and the contribution Roamer made to it was changed. This was acceptable and is always a possibility in constructionist projects. However, in general:

- Big projects like this should not be used to teach students how to program the robot, they should know before hand - this allows them to concentrate on the other curriculum issues - in this case writing the dramas
- While the school understood and practiced Assessment for Learning (AfL), preparation for using these techniques was not sufficient. Consequently learning intentions and success criteria were not clearly established [11].
- The robots should have been used on some smaller activities earlier in the week

These are not criticisms but practical lessons to be learnt.

## VIII. E-ROBOT

When the No Child Left Behind Act (NCLB) was launched in the USA it made a statement that only “scientifically based educational research” was of value [12]. This essentially values positivistic research and dismisses qualitative methods. Catlin and Blamires [2] refute the stringency of the NCLB approach, but accept that the research basis supporting educational robotics has its problems. For example, if we focused on this specific activity as a case study, how do we relate its findings to similar or even radically different educational robotic activities?

The ERA Principles provide the framework for evaluating an educational activity or method. It is flexible in that it can accept data from observational studies like this, or large scale quantitative methods described under the positivistic philosophy.

Even though the positivistic methods often claim to be longitudinal studies, in real educational terms they are not. The e-Robot project aims to gather data from the educational robotic community through online social networking on an ongoing basis. Because it is community based it has no time limit. A recent paper published by the UK Government takes a similar approach to the NCLB approach [13]. Like the NCLB approach this paper is recommending the medical model of research as its guide. It is an indication of trend that will become prevalent in education. e-Robot aims to gather data in response to this future demand.

This report provides a form of qualitative analysis against the ERA Framework. This is an interesting instantiation, in ways typical of educational robotic research. It is clear that so much more could be done to gather better data, structure the analysis and synthesise the data with results from other projects.

## CONCLUSIONS

This project gathered positive evidence confirming some of the ideas of ERA. It showed the desperate need to develop research tools and metadata structures that can better shape the design of qualitative research, its analysis and synthesis with data from other projects. This is subject to ongoing development.

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