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Educational Robots and Mathematical Modelling

Exploring the use of Turtle type robots in High Schools

Dave Catlin
Valiant Technology Ltd.
London, United Kingdom
dave@valiant-technology.com

Edward Otieno
Mathematics Department
Kingsdale Foundation School
London, United Kingdom

***Abstract*— Do Turtle type educational robots have a role to play in High School? In general the use of these robots is in early years and primary schools. In High Schools the use of Lego and Vex construction type robots predominate. According to the Educational Robotic Application (ERA) Principles Turtle type robots can support the development of older students. This poster reports on a pilot project exploring this principle using the Roamer® robot. The project showed how robots can make a positive contribution to enriching a student's mathematical experience and provided important insights on how to improve the organisation of robotic activities.**

Keywords—Turtle, Logo, Roamer, Educational Robotics, Mathematical Modelling, Educational Robotic Application Principles, ERA Principles, Embodiment, Valiant Technology

I. Introduction

The first educational robot was developed in 1969 [1]. The Turtle robot was the brainchild of Seymour Papert as an extension of his program language LOGO. This was designed to enable even young children to use programming as a pedagogical method. The computers used at the time were PDP-1s. They were housed at MIT or BBN Technologies Inc.[1] and the school connected to them via teleprinters. VDUs (Visual Display Units) did not exist [2]. The Turtle robot provided students with something they could visualize and manipulate. However, examination of the 62 Logo Papers written over a ten year period between October 1971 and October 1981, shows that the vast majority of work was done with virtual robots [3]. This also reflected many Logo publications [4], [5], [6], [7].

Catlin and Blamires postulated The Educational Robotic Application (ERA) Principles [8]. This meta-analysis of work with Turtle type robots since their inception results in a framework of ten principles against which the outcomes of efforts with educational robots can be evaluated and correlated.

In the heyday of Logo, Turtles were used in primary schools and students "graduated" to screen Turtles in high school. This was consistent with Piagetian Stage theory which in part underpinned Logo. This poster reports on work aimed at exploring the thesis that the concrete nature of Turtle robots can enrich the experience of older students. The ERA Embodiment Principle states," *Students learn by intentional and meaningful interactions with educational robots situated in the same space and time*." This principle makes the claim that there is at least a qualitative difference in a student's experience with a physical and virtual robot. This is a conjecture which is subject to ongoing research. The Roamer was used in this project which is programmed directly through its onboard keypad using a derivative of LOGO [9].

II. Project Setting and Objectives

This poster reports on work aimed at exploring the thesis that the concrete nature of Turtle robots can enrich the experience of older students. Turtles focus on Teaching With Robots, and this activity aims to develop student's ability to use mathematics to solve practical problems.

The ERA Pedagogical Principle identifies 28 different ways of using robots in an educational environment. This activity includes: Mathematical Modelling, Presentation (a means for students to explain their work) and the Provocateur (inciting thinking and discussion). In this case discussions about the nature, use and morality of statistical data. The ERA Curriculum and Assessment Principle implies that activities should not focus on the robot, but the educational value of the student. In this type of activity the robot plays an important, but only a supporting role that augments this experience.

The project took place in an after school mathematics club in Kingsdale Foundation School in South London with a Year 9 students (14 year old). The authors have noted number of characteristics of such clubs which effect the learning environment: 1) They are voluntary and take place in a more casual atmosphere than normal lessons 2) Students are tired and less attentive after the school day. Maths teacher Edward Otineo and Valiant's Dave Catlin and Kate Hudson supervised.

III. The Challenge

The students were asked to design and model a bus service for a small town[2]. They were given the town map shown in Fig 1, showing buildings, building function and occupancy/usage details. The students were made aware of some of the design issues used in the development of mass transportation systems: Service Levels, Standard Service Periods, etc. [10]. This project is very open ended with multiple possibilities for extending it in a variety of directions for example: visits by local bus companies or transport museums, data gathering in

[1] The company who ran the project that invented LOGO and Educational robots.

[2] This reports on the activity "On the Buses" is covered by Creative Commons License BY-NC-ND. Attributions should be made to Valiant Technology Ltd.

the field like timing people getting on and off of buses and how journey times vary according to traffic conditions.

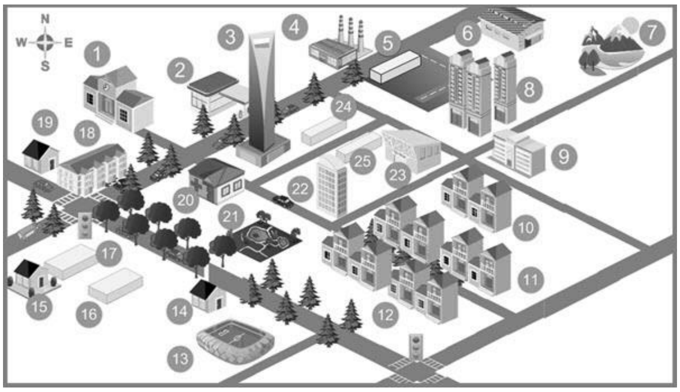

Figure 1 The town map.

IV. THE ACTIVITY SESSION

Students engaged with the design problems and thinking through the issues involved. One group became fixated on buses going to the sports stadium, whereas others realised that a normal bus service could never satisfy match-day demand for transport and it required a special service. The first group eventually realised this when they came to create the bus time tables. This was an indication of a positive contribution made by the activity. It was clear that the students had the mathematical knowledge to solve the problem, but struggled to apply that knowledge to resolve the practical problem – certainly they struggled to do so in an efficient way.

The activity provoked a wider debate about statistics and their use. An example of this was a discussion of how the State of Arizona could reliably use the reading scores of 3rd graders to predict how many prison beds they would need in the future[11]. The students considered the statistics prejudicial and unethical. A lively discussion pointed out the neutrality of statistics. The UK uses the same statistics to plan preventative interventions. A detailed account of the work done, written by the students is available online [12].

V. STUDENT LEARNING AND EXPERIENCE

What is the point of Arizona prison statistics? First it occurred in the debate. But it was also indicative of a transformation in the students perspective about statistics. Normally school statistics is about data provided by the teacher and learning a set of manipulative techniques. In this activity students began to see them as way of evaluating situations and solving problems that had wide social impact. On a practical level students did not understand how to make mathematical judgments when the data supplied was not specific enough to solve the problem. The challenge helped them appreciate they were creating a mathematical model which would be tested and revised. So they were free to make assumptions understanding that in practice such a model would be field tested and then adjustments made to the model. They also became aware that the mass transit industry used data gathered over many years to help them devise effective bus schedules, but they would still take care to build and then test their models. Specific data on the students response to the activity was not gathered. However a key indicator is that the students were inspired to attend the workshop for 5 weeks. In these types of workshops students stop attending if they have no interest in the task.

VI. THE VALUE OF THE ROAMER

The fundamental question is what did Roamer add to the project? Apart from the suggestion that using the robot to introduce the activity might have some benefit had there been no need of it so far? Mathematics teacher Edward Otineo said, “*I think that using the robots was beneficial to the pupils as it added a practical dimension to the whole project. The visual element of the behaviour of the robot helped even though it depended on the robot being programmed correctly. There was the issue of calculating distance of their chosen routes which I think was helped by the use of a robot. I also think that they were just fun to handle and programme*.”

Viewed from the holistic perspective on the activity the robot did provide a focus – the production of a mathematical model. But this activity demonstrates the ERA Practical Principle by showing how easy it is to create an interesting scenario without needing the expense of software development.

VII. CONCLUSION

One of our motivations behind this activity is exploring the use of robots in a subsidiary role. As smarter robots become less expensive we predict this type of application will become more prevalent. This pilot project helped us to understand how to improve the planned repeat activity. We presented the problem to the students top-down. This was a mistake. In a manifestation of the ERA Engagement Principle the students were eager to use the robots from the start. In retrospect we should have utilized this enthusiasm to introduce the activity via a bottom up approach. More attention should be paid to the group sizes to ensure students are kept busy. The inclusion of a physical robot did seem to impact the activity.

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Educational Robots and Mathematical Modelling

Exploring the Use of Educational Type Robots in High School

Dave Catlin (Valiant Technology Ltd) and Edward Otieno (Kingsdale Foundation School)

Introduction

Traditionally Turtle type robots have been thought of as tools for primary school education. This Project shows how to enrich the experience of older students by using the Roamer to help design and mathematically model bus routes.

Fig 1: Turtle type robots: the Valiant Turtle, Classic Roamer and Roamer.

Roamer®

Derived from the original Turtle these Roamers are primarily used in a TWR (Teaching with Robots) context. A cut-down version of LOGO software is embedded in the robot's microchip and is normally programmed through its onboard keypad.

Turtles Vs Construction Type Robots

The game below aims to develop a student's estimation skills. Children estimate distances then program Roamer to travel forward to their target. The one who scores the most wins. The teacher needs to be able to be able to set up the robot and activity within one or two minutes of the start of the lesson.

Fig 2: Six year old pupils using Roamer to develop their estimation skills.

These kinds of activities make the use of the technology accessible to many teachers who lack technical skills.

Activities like this are prevalent in Primary schools. Is there an equivalent class of activity suitable for high schools?

Project Objectives

The project aimed to make to enrich a student's mathematical experience and help further our understanding of this type of activity in high school.

The Challenge

To design a bus route for a small town. Students were asked to:

1. Decide the bus route
2. Situate the bus stops
3. Create a bus time table
4. Use Roamer to model and test their time table

Fig 3: Map of a small town showing the buildings.

Students were provided with the town map and information about the function and occupancy of each building. Initially they struggled to understand how to estimate how many people might be using the bus at any time. Eventually, they realised the purpose of the mathematical model was to create something that could be tested. They then used the data to make a best estimate. Programming the robot to test the idea showed up a number of anomalies in their design which they then improved.

Weekdays	Bus Frequency	N° of Passengers	Weekends	Bus Frequency
5am to 7 am	20 mins	45	5am to 7am	30 mins
7am to 10m	6 mins	37	7amto 10am	20 mins
10am to 2pm	30 mins	38	10am to 8pm	12 mins
2pm to 4pm	10 mins	18	8pm to 12pm	18 mins
4pm to 8pm	6 mins	28	12pm to 5 pm	30 mins
8pm to 12pm	20 mins	10		
12pm to 5am	40 mins	6		

Table 1: Example time table created by the students.
The students did not calculate the Number of passengers travelling at the weekend because of time limitations.

GO You can see the students' report on the project on http://goo.gl/D49OoX

Kingsdale Foundation School Maths Club

The project took place with Year 9 (14 Year olds) gifted maths students. After school clubs are more casual than formal classes and students tend to be tired at the end of the day. Attendance is voluntary. The high turnout for the 5 weeks project is a marker of student interest in the project.

Fig 4: Students develop their models. Most of the work does not directly involve using the robot.

Robot does not need to be the main focus to the activity.

They can play a valuable supportive role.

If the use of educational robots is to become widespread and fulfil their potential there will be a lot of activities where the robot plays a supportive role. This project is one of several where this idea is being explored.

Fig 5: Tape was used to layout the streets then the students used Roamer to test their models.

Enrichment

After school clubs offer the opportunity to use broader, more experimental approaches to learning. Generally, a students experience of statistics is being given data by the teacher and learning how to manipulate it. The robot provided them with a different goal. Instead of stopping with the production of the bus time table they had to provide a dynamic demonstration of their ideas. Viewing this activity holistically the activity provoked passionate discussions about the nature and ethical use of statistics.

ERA Principles

The Educational Robotic Application (ERA) Principles is a framework of ten elements aimed at helping to evaluate and develop educational robots and their activities.

Conclusions

The Educational Robotic Application (ERA) Principles is a framework of ten elements aimed helping the development and evaluaton of educational robots.

ERA: Embodiment—The physical robot provided

ERA: Curriculum and Assessment—This activity did provide students with an augmented and practical experience of statistics beyond which they get from normal teaching approaches. The demonstration of their model provided the teacher with a way of assessing the quality of the student work.

ERA: Pedagogical Methods—There are 3 methods evident; mathematical modelling, presentation (of their work and ideas) and the provocateur (the creation of an environment that provokes the children to think and debate issues and ideas).

ERA: Engagement —The students were attracted and excited about using the robot. We can improve the activity by using this motivation to present the activity in a bottom-up fashion (we used a top-down approach).

ERA: Sustainable Learning — This is lifelong learning and includes things like problems solving and working as a team.

ERA: Practical — The ability to quickly set up the activity and modify it to suit the group makes it adaptable and practical.

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Roamer www.roamer-educational-robot.com

Contact

Dave Catlin dave@www.valiant-technology.com