Using Peer Assessment with Educational Robots

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Abstract. Educational robots offer tremendous potential for providing exciting, dynamic learning experiences in K-12 Education. The constructionist notions of Piaget, Papert and others underpin the use of this technology. A problem exists in ensuring successful lessons using these paradigms. The root of that problem is the imagination, curiosity and creativity of students. How can that be given free reign while at the same time trying to meet the rigid demands of a school curriculum subjected to the hegemony of high-stake-testing? Seminal work by Black and Wiliams summarized what can be called good teaching practice – the key to resolving this conundrum. Their development of Assessment for Learning (AfL) strategies offers a way of structuring lessons while fostering essential intellectual freedom of the student. Peer assessment is a key part of AfL. This paper explains and illustrates how peer and self-assessment is an intrinsic aspect of educational robotic activities.

Keywords: Peer Assessment, Self-Assessment, Educational Robots, Constructionism, Papert, LOGO, Turtles, Roamer, Assessment for Learning, AfL, Black and Wiliams, TWR, Teaching with Robots.

1 Introduction

The aim of this paper is to explain the role of peer and self-assessment (PASA) in the successful use of educational robots. It is not a review of the value of PASA; it is about how PASA is applied with educational robots. The first part of the paper briefly summarizes relevant aspects of educational robotics. It describes some of the issues that effective use of technology has to address. It has been proposed that Assessment for Learning (AfL) will resolve these problems [1]. PASA is a key part of AfL methodology. The rest of this paper illustrates through examples how these assessment processes are a natural part of work with educational robots.

adfa, p. 1, 2011.

2 Educational Robots

In 1970, Seymour Papert invented the first educational robots called Turtles [2]. Students controlled the robot by writing programs in LOGO, a computer language developed especially for education. It is a constructionist tool, providing an environment aimed at helping students improve their ability to learn. It is also a philosophy of education opposed to what Papert termed instructionism where the teacher acts as a dispenser of knowledge [3]. This does not mean the teacher should never tell children things; Papert called that idea silly [4]. What he suggested was the creation of microworlds: learning environments which were rich in ideas and challenges that motivated the children to become explorers of knowledge. LOGO and the Turtle were explorer's tools. The teacher becomes a guide whose purpose is to ensure the student maximizes their learning experience. It is wrong to think that because LOGO and Turtles have been around for a long time, that these are yesterday's ideas. Papert's work created a paradigm in the Kuhnian sense, that is still relevant today.

In 1989 the development in the UK of Roamer followed by PIP put a simplified derivative of LOGO into a Turtle. Students programmed these robots using on-board keypads. Modern robots like the current Roamer, still use the programming paradigm, but facilitate more natural interactions using HCI, HRI and tangible computing technologies. This paper focuses on these Turtle type robots, not the construction type robots like Lego (launched in 1999). There are overlaps, between the two types, but as a rule-of-thumb, TWR (teaching with robots) is the forte of Turtle type robots and TR (Teaching robotics) is the province of construction type robots.

Activities and robots that conform to Educational Robotic Applications (ERA) Principles provide the opportunity for students to be active learners in an environment that encourages thinking, creativity, curiosity and the development of imagination [5]. The claim is that they do this by providing students with concrete constructivist experiences which when linked to traditional teaching can enhance and deepen a student's understanding of curriculum content. ERA principles homogeneously combine to provide a community based learning environment which has the ideal mixture of Learner, Knowledge and Assessment elements [6]. The connection between ERA and PASA is made in the conclusions.

3 Praxis Problems

Clements and Sharma claim that if implemented correctly LOGO provides an educational environment that has few equals [7]. Yet improperly implemented, its results can be trivial. Others also report this inconsistency and discussed the various issues that affect the implementation of LOGO [8] [9]. Papert said of his creation, not everything done in the name of LOGO is in the spirit of LOGO [10]; essentially he is referring to people using constructionist tools in an instructionist way. When children are exploring things, they will get ideas and inspirations that were not in the teaching plan. You now have engaged enthusiastic learners. Whether their ideas are good or bad, the potential for learning is enormous. But the strictures of the curriculum urge you strangle this eagerness and move on.

The easy option is to shortchange our children and teach to test. It takes a lot of courage and confidence to implement the constructionist approach intrinsic in educational robots. Clements and Sharma point out; it also requires the buy in of administrators, curriculum developers, teachers and students. The teacher is the key. It is recognized that teaching is both an art and a skill. This has nothing to do with robots. See the exemplar Fleet Circus – a design technology project run by an exceptional teacher Trevor Thompson [11]. This project perfectly illustrates a teacher nurturing the imagination and creativity of students and still delivering good test results. The challenge is how do you capture that? AfL offers an answer.

4 Assessment for Learning (AfL)

Professors Paul Black and Dylan Wiliam of Kings College, London claimed that governments judge school performance by treating them as though they were a black box [12]. They monitor what they put into schools (investment) and what they get out (return) measured by what has become called high stakes testing. Black and Wiliam's research focused what went on inside this black box, specifically what went on inside the classroom: the mechanics of what transforms input into output. How does a teacher interact with the student? What type of interactions will help raise standards? Clearly the answer is epitomized in Trevor Thompson. AfL essentially codifies his good practice. AfL consist of four elements – see Table 2 adapted from Smith [13].

Table 2. Elements of AfL

Element	Explanation
Learning Intentions	The student's perspective on what they are learning.
Success Criteria	How will the student recognise when they have successfully completed the assignment.
Quality interactions and feedback	Understanding in real time if the students understand or are confused by anything in the lesson. How the teacher responds to the feedback, interacting with student to help improve their educational experience
Peer Assessment and Self-Assessment	What students think about their work and the work of their classmates – conducted in a way that helps improve the quality of their understanding

5 Peer and Self-Assessment with Educational Robots (PASA)

5.1 Methodology

The section illustrates how PASA is an intrinsic aspect of educational robotics, and how a range of methods of implementing PASA can be integrated into educational robotic activities. These are presented through a series of activities. The activities are described and then the PASA element discussed. Most of these examples are supported with online materials which provide more information. The examples are drawn from Valiant Technology's research archive which contains over 30 years of work with schools all over the world. Although most of the activities relate to work done with the educational robot Roamer, the principles apply to any similar robot system. Moreover, the examples are not singular occurrences; they are representative of a wide range of exemplars. First let us look at some early research findings.

5.2 Early Research on Floor Turtles

Between September 1987 and December 1988 a National Floor Turtle project was run in the UK involving schools in 21 participating education districts [14]. This research used 350 Turtle type robots, all programmed from LOGO on the computer and supplied by different companies. It was done at a time before any academic concept of AfL or PASA existed. Some of its conclusions heralded the future:

- One of the difficulties faced by teachers was knowing when to intervene, and when to allow children the freedom to make and learn by their 'mistakes'.
- It was a feature of early work in project schools that teachers tended to set tasks for children to carry out, whilst they gained experience in the use of LOGO and the floor Turtle. Later, it was evident that teachers had gained sufficient confidence to permit children to initiate their own activities.
- The two most common areas where the participating teachers note improvement were in the children's involvement in their work and their interaction with each other. Greater self-confidence, fewer inhibitions, and more practical activity leading to easier discussions were all identified.

This illustrates four key issues:

- The nature of teacher involvement
- Ability of students to manage their work
- Students engagement
- The interaction between students and student confidence

All of these points contribute to an environment that supports PASA.

5.3 Robot Activities and the Role of the Teacher

PASA is a natural aspect of most robotic activities. In the activity The Adventures of Myrtle the Turtle a scenario is set where the robot travels back in time and meets various people. In the process she helps invent geometry. In the first activity she meets a caveman trying to build a bridge across a river. She helps by swimming across the river and telling him how far she went. The children program the robot to move forward a number. The number represents the distance travelled by the robot. The student has to decide on a unit, estimate the distance, test that estimate with the robot. Chris Gregory explains, "*Practical measurement of length, weight, capacity,* *etc. is a common feature of early mathematics work. Unfortunately this often becomes the manipulation of standard units and the use of ready-made measuring devices*." He goes onto explain how using a robot engages the students with all the basic facets of measurement from choosing units to deciding whether they have a viable answer given the practical context[15].

With robots students normally work in groups. Valiant's research has noted that even simple activities like this involve the students sharing, discussing and evaluating each other's ideas on an almost continuous basis.

The teacher's role in this process is that of observer and facilitator or guide. The notion of teacher as a facilitator or guide has become common currency. The importance of observation is less prominent. Deputy head Anne Butler from Hotwells Primary School in Bristol, England stressed the value of stopping teaching and watching and listening to the children. Robot activities provide the teacher that opportunity. The interactions students to student and students to robot become public. The teacher can observe this and decide whether or not to intervene and what form that intervention should take. Sometimes the students simply need factual information or clarification. But on other occasions they need to think more deeply about an issue. The teacher can encourage this through a series of techniques called "effective questioning" [16]. The aim this type of interaction is not to get the pupils to providing answers, but to promote a debate amongst the group about a relevant area of knowledge. Another situation, where students present their thoughts to scrutiny of their peers.

5.4 Star Wars Activity

ICT teacher Nick Flint decided to use Roamer in a Star Wars Project. This activity took place at Maple Cross School in Rickmansworth, London. It was part of a week where the focus was on Art and Design, Math and English. The class consisted of Year 5 and Year 6 students (9 to 11 years old) [17].

A lot of robot projects involve significant amounts on non-robotic work. This particular project started with an Art and Design activity where the pupils made a Star Wars town. Valiant researchers visited on the day students were scheduled to script and produce robot videos. The students had never used the robot before, so they also had to learn how to program it. The classes were split into production groups. Initially each student was tasked with drafting an outline script for the video. The next part brought the team together in a script meeting. In this session each student presented their ideas, which was reviewed by the team. Following this assessment the group selected a script for development. In one case a team chose to amalgamate two ideas. The teams then spent the rest of the day learning to program the robot and producing the video [18].

PASA was a continuous aspect the day's interactions. Students were faced with problems, had ideas about solving them, shared their ideas and discoveries. The other team members reviewed the ideas provided feedback and eventually decided how to proceed. Three adults were involved working with the students, but their role was largely time management and answering technical questions when asked by the different teams. This type of scenario is common with robotic activities. An essential characteristic for success is an affirmative learning environment where students trust each other's comments and opinions. It is a positive aspect of peer assessment that it is easier to accept criticism from your fellow students, than it is from adults. Maple Cross had obviously worked hard on developing that attitude amongst its students. This did not mean the day was without it traumas. One child (who has a difficult home environment and noted personal problems) did get upset and destroyed his model building. What was impressive was the way the teachers and students dealt with the situation. After an hour the pupil was back on task receiving positive support from his peers.

After the event, Nick Flint set the students the task of writing a news article about the day. This idea represents a great opportunity to engage students in reflective thought. We plan to investigate how we can structure this type of task so that students do more than present a narrative of the day, but encourage them to assess their learning [19].

5.5 Self-Realization

In the late 1990s Professor Christian Sarralié of CNFEI in France reported working with adolescent students who had been brain damaged in automobile accidents. One student had lost the ability to perform simple arithmetical operations. He could not accept this situation and indeed in his mind he was a top performing math student, despite contrary evidence in his education record. The pliability of the brain and the nature of their condition meant that he could regain much of his mathematical ability. However, he reacted aggressively when teachers tried to engage him in basic primary school math. The teacher then gave him an activity using the Roamer robot. This required him to perform some basic arithmetical operations. The robot's non-judgmental neutrality acted as a mirror, reflecting his thinking [20]. His assessment of his mathematical knowledge radically transformed making him amenable to the learning process.

5.6 Internal Dialog Externalized

Valiant once received a report from a school in Northern Ireland that the teachers had noticed a young girl talking to the Roamer as if it were a pet. They realised from the conversation that the child was suffering abuse. They took appropriate action.

MIT's Sherry Turkle describes how our contact with the world and the concrete objects in it, evoke thoughts, feelings and emotions [21]. Turkle is also one of a number of researchers who have investigated how this phenomenon applies to robots [22]. It is an aspect of the ERA Engagement Principle that students form a bond with the robot. Even though they know it is a machine they act with it as if it were sentient. This phenomenon is not confined to young children. Turkle's research looked at robots as cyber-companions with the elderly. What Turkle has shown is that the dialog tends to reflect the child's inner concerns and struggles. For example one pupil who had a medical condition was persistently making sure the robot was well looked after. Although it is not strictly PASA, it does indicate mental processes which a skilled educational psychologist might be able to use to help a student. It is also an indication of the future potential of robots to become more than a passive peer reflecting a student's ideas.

5.7 Design Process, Inspiration and Show and Tell

The Dog House activity challenges the children to make a robot dog. This is a good example of the ERA Pedagogical Principle. It involves students in a range of different types of tasks: research on animals and dogs in particular, observation of dog behaviour, and analysis of data, mathematical modelling, programming, testing and debugging the programs. Creating a robot dog is like creating an animated sculpture. It is not a dog; it's a robot that makes you think of a dog [23].

This activity illustrates four ways educational robots engage PASA. The first two of these are inherent in the Design Process. All designs go through a recognizable set of phases, starting with the specification; what do I want to design? Gathering information, thinking of possible designs, evaluating these ideas, designing, making the design, testing and modifying and finally evaluating and reviewing the design. At each stage all previous decisions are reviewed. For example, do I get an idea that makes me want to change the specification? In the Dog House activity the students worked on individual projects, so this was an exercise in the students assessing their work and improving it based on those assessments. The dynamics would have been different if it was a group project and the process would be a peer assessment process.

Robots are highly visible and students notice what other students or groups are doing. It is quite natural for students to be inspired by the work of others. In the traditional classroom this might be deemed copying. In this environment it is learning. An excellent example in occurred in the Fleet Circus Project. Some of the boys had noticed the girls making characters out of Flymo clay. This made heavy figures they wanted for their design. They not only used the same materials, but they spontaneously 'subcontracted' the girls to help them make the parts they needed!

At the end of an activity like this you can hold a "Dog Show" – a show and tell experience where the students explain their research, ideas and design. Their fellow students can ask them questions and engage in a peer assessment process.

5.8 Project Management, Questionnaires and Plenary Sessions

In this activity students are presented with a scenario where a space craft has crash into a canyon. As a rescue organization students have to send their robots to the scene of the disaster and retrieve this expensive piece of hardware p24]. This will involve them building a structure that they can transport to the site. A variety of found materials are available to make the structure, but each item they use will cost a certain amount. The stronger materials are more expensive than the weaker materials. The activity breaks down into a number of different tasks which need to be completed simultaneously. This involves different team members working by themselves or in pairs on one task. They need to bring their work together. It is a chance to appoint a project manager, whose task is to oversee the completion of a viable solution. This affords the opportunity to review each other's effort, find integration problems and resolve them.

At the end of the task we used a questionnaire to gauge the student's reaction to the activity. The efforts in this example were restricted to handing out the forms at the end of the activity – the students filled them in as they were clearing up. Nothing particularly unusual in that, except it is missing a golden PASA opportunity. It is possible to make such efforts far more meaningful. First ensure the questionnaire endeavors to find out what the students felt they learnt. Stop all activity, and get each group to complete a single form. This immediately involves them in reviewing, discussing and sharing their experiences.

The final strategy is to allow time for an assessment plenary. This should be used with most activities not just the Space Craft Rescue project. In fact the Dog Show is an example, given a structure by the nature of the activity. In this case the teacher can lead the discussion, by choosing comments from the questionnaires and opening them up for the whole class to review and discuss.

6 Conclusions

Peer and Self-Assessment are intrinsic facets of educational robotic activities. Students normally work in groups and the practical and authentic nature of the activities provides an environment where sharing of ideas, the discussion of problems, the creation of solutions, the review and modification of those solutions is a continuous aspect of such activities. The teacher's role in this is that of guide and her main tool is effective questioning, which is a way of engaging groups of students to review each other efforts.

The cited examples illustrate how PASA relates to aspects of ERA:

- The Curriculum and Assessment Principle provides the most obvious connection with PASA. While Papert was focused on revolutionizing schools, this principle aims to integrate his core ideas into everyday teaching practice. Clearly a big part of that is assessment and designers of educational robotic activities find PASA is a convenient way of satisfying this requirement.

- The Practical Principle is really about getting the buy-in cited by Clements and Sharma. The PASA related observations made in the Turtling without Tears report have been consistently reported by teachers over the last 3 decades. Teacher's constantly seek ways of creating situations where students are able to engage in PASA experiences and find robots a useful way of succeeding in this effort.

- Another persistent observation of robot activities is their ability to connect students with the Sustainable Learning (Lifelong Learning) Principle. The proclivity of robots to involve group work provides the opportunity to develop cognitive, social, personal and emotional traits. The Star Wars activity is an example of how educational robots create the opportunity for student interactions to assume the beneficial characteristics of PASA.

Consciously applying PASA ideas to educational robotic activities is relatively new. This review of a few historical examples of work done with robots is typical of experiences with educational robots. It reveals that over the last 3 decades, the latent and unreported contribution of PASA to the success of this technology. It is now clear that there is great potential for these ideas to enhance the effectiveness of the technology. This requires a partnership between PASA research and design. The latest Roamer for example, has been developed so that it is capable of far more than acting as a mirror. The limitation is not technological, but an understanding of how robots can be more active PASA agents.

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