Classroom Maker Projects and User Bots

Dave Catlin

Valiant Technology Ltd
dave@valiant-technology.com

Abstract. The EduRobot Taxonomy identifies three basic types of education robots: Build, User and Social Robots. As its title implies, we associate Build Robots with maker-projects where students mainly learn from making a robot. Students learn with User Robots, like Turtles, by using them to solve problems and engage with invaluable experiences. However, just as you can make a Turtle robot from a Build Robot, you can utilise some User Robots as platforms for maker-projects. This paper reviews thirty years of maker-projects involving User Robots. I'll present examples from different continents, cultures and social-economic groups. Although I'll cite a few research projects, this isn't a research-driven paper. It's chiefly a report on the work of experienced classroom teachers delivering regular lessons to students aged between 4 and 18-years-old. It explains how they used robots and maker ideas to meet curriculum objectives for students of varying abilities. Using this evidence, we'll gain a broad appreciation of classroom maker-projects featuring User Robots and glean a few helpful tips you might find useful. We'll also detect the authenticity of this bottom-up approach - it shows what happens when experienced teachers use robots effectively.

Keywords: Education Robots, Maker Projects, Build Bots, User Bots, Turtles, Design Technology, Roamer

1 Introduction

The EduRobot Taxonomy[1] defines three types of education robots (Catlin, et al., 2019):

- Build Robots: Students learn by building the robot.
- User Robots: Students learn by using pre-built robots.
- Social Robots: Students learn by interacting with autonomous robots through Human Robot and Human Computer Interfaces (HRI and HCI). These robots don't figure in this report.

Despite being a mammal, the duckbilled platypus has several characteristics associated with reptiles, but these don't change its nature - it remains a mammal. Similar-

[1] See www.robots-for-education.com for full details

ly, you can make a Turtle from a Build Robot like Lego - but it's still a Build Robot. If you employ a User Robot as a platform onto which you build a robot, it remains a User Robot. This paper presents examples of User Robot maker projects spread over three decades and taken from Valiant Technology's archives. Teachers of students aged from 4 to 18 years-old, initiated most of the projects as part of regular lessons: a few examples stem from special events, after school clubs and research efforts. I also link these examples to five of the ten Educational Robotic Application (ERA) Principles, which I use to summarise and compare the value of education robots from different types of project (Catlin & Blamires, 2010) [1]:

1. **Embodiment**: the advantages of physical over virtual robots.
2. **Engagement**: the attraction many children have to robots and their excitement when playing with them.
3. **Personalisation**: the ability of robot to personalise the learning experience.
4. **Curriculum and Assessment**: how robots support good teaching practice and expose children to the curriculum in appealing ways.
5. **Practical**: Robot tasks must make it simple for teachers to use in lessons.

Most of the examples involves design-technology, a subject started in the UK, which later spread to America, Canada, Australia and New Zealand. I'll explain how design-technology started as a school-based version of the maker movement. Education's focus on testing has strangled the tinkering spirit out of design technology schoolwork. I'll show how the maker movement and User Robots can help revive it.

2 Design Technology and Maker Spaces

In the 1970s, the UK saw the start of a transformation in traditional woodwork and metalwork lessons. Teachers realised learning craft skills wasn't enough: students needed to learn about design, electrical and control engineering[2]. In parallel with this bottom-up revolution, the education department at Nottingham University started to explore the idea of design technology replacing craft lessons. This took off. Throughout the 70s and 80s, teachers, researchers, education authorities and the engineering institutions embraced the ideas. In 1980, computers started to go into British schools. The National Computing Centre had already identified the importance of students learning how to

Figure 1 Fleet Circus Project 1998 - The Human Cannon Ball. One of the many circus automatons designed by 11-year-old Lincolnshire students and made out of junk materials. The clown raised his hand; the barrel tilted up; lights flashed and the cannon fired out the doll.

[1] For full technical definitions see the freely available online reference.

[2] Information from interview with Alan Paul, Senior Lecturer at Nottingham University.

use computers in control engineering projects (Figure 1 Computer Controlled Circus Act) (Catlin & Thomson, 1998).

When in 1989, the UK first introduced a National Curriculum, it included design technology as a core subject. In the seventies and eighties the subject had trickled down from High Schools to Primary education. In the mid-nineties the USA launched the Technology for All Americans Project (ITEEA, 2007), intending to modernise their Shop subjects: Australia, New Zealand set up design technology curriculum. In those formative years, the same spirit that inspires today's Maker Movement motivated design technology, its teachers and students. However, I believe, high-stakes testing and government curriculum reforms helped stifle the essential tinkering spirit in favour of learning specific content. Our challenge is to find a way for the maker movement to revitalize this subject.

2.1 Thinking Like a Designer

Similar to the current belief in the benefits of computational thinking, educators proposed the design process as a meta-thinking skill (Figure 2) that would help students learn all subjects (Todd, 1999). Yet, I discovered teachers of other subjects didn't agree. Students undoubtedly learnt, for example, about science through design and make, but science teachers wanted to teach students to think like scientists - not designers. This applied to art teachers, maths teachers – all subject teachers.

Figure 2: The design process includes: Research, design, making and testing - which in the case of Roamer includes programming and testing the program. These girls made a robot explorer in a geography lesson. They programmed Roamer to follow compass directions and scaled their journey's program to draw a map.

More importantly, meta-thinking is an emergent property that comes from experience. Trying to bolt-it-on from the outside doesn't work well (Lave & Wenger, 1991) (Catlin & Woollard, 2014). It's like learning to become and artist through painting by numbers: you'll learn something, but you'll sacrifice flair and creativity. I believe ensuring you teach specific content does the same, and the spirit of the maker movement can revive this essence. We need to keep tinkering and creativity at the heart of the enterprise and play down, but not abandon the focus on process.

3 Example User Robot Maker Projects

3.1 Engagement

Sherry Turkle reports how we treat robots as though they're alive - even though we know they're not (Turkle, Taggart, Kidd, & Daste, 2006). We develop bonds with robots, similar to our connection with family pets. Children talk to their robot and sometimes confide their innermost thoughts and fears. Tragically, for example, teachers in Northern Ireland realised from a little girl's conversation with Roamer someone had abused her. Making the robot into a character (Figure 3) personalises the robot and increases the child-robot bond[1]. It creates a chance to involve children in excellent art and craft projects and introduces them to simple making skills and tool safety. What makes their efforts special – is their ability to bring their creations to life. Sherry Turkle cites eleven-year-old Deborah who said, "When you program a computer, there's a little piece of your mind and now it's a little piece of the computer's mind" (Turkle, 2005). This readily transfers to working with User Robots.

In the Incy Wincy Spider task, the robot sings the verses of the popular nursery rhyme in the wrong order. The four-year-olds who play this game know the rhyme's verses, but don't grasp what they mean. By programming the robot to sing the verses in the right order they think about the meaning. And making the robot look like a spider draws them into the task (Figure 4).

Figure 3: Preschool children making Roamer characters – a task similar to the toy Mr. Potato Head – it helps them bond with the robot.

Figure 4 Making Roamer into a spider added appeal to the Incy Wincy Spider task – see the video reference (Dale, 2017).

[1] A 1989 laboratory experiment run by Valiant Technology.

3.2 Craft, Art or Technology?

Historian, Joel Mokyr, claims we reserve the term technology for the latest inventions and downgrade yesterday's innovations to craft status (Mokyr, 1990). You'd rightly classify all the designs I've cited so far as craft projects - perhaps for young children, you might stretch that to include art. Where design technology concentrates more on engineering, maker projects are more eclectic (Dousay, 2017). This fits well with User Robot projects where the differences between craft, art and technology become blurred. The art teachers in Harrow Schools, England, ran a district-wide art project designing and making robot insects (Figure 5).

Figure 5: The younger children created moving sculptures (left) while they artistically explored materials, textures and forms. Older students covered the same skills but started to include mechanisms to flap wings and sensors to avoid obstacles (right).

3.3 Technical Projects and Maker Spaces

Dousay correctly defines the features of maker spaces to include technology, tools and personnel [skills] across all forms of technology. Typically, Primary schools don't have workshops or specialist design technology teachers. In the UK massive training programmes tried to upgrade the technical-skills of at least one design technology teacher in each primary school and expected them to train the rest of the staff. This seemingly reasonable strategy had mixed results. The maker attitude allows you to work with the existing art and craft skills of most Primary Teachers. In the Fleet Circus project Headteacher, Trevor Thomson, always drafted in help from the local community when the children's imagination demanded expertise he didn't have. In

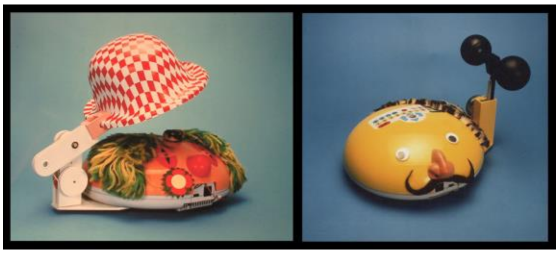

Figure 6: Coodies Circus: characters in a circus movie made by ten-year-old students. Help from the community gave the students the knowledge to go beyond arts and crafts: the clown lifted his hat and flashed his eyes and strongman raised and lowered his dumb-bell.

1989 Alan Coode, head of Southmead Primary School in South London did the same with another Circus Project (Figure 6) (Coode, 1989). Unfortunately, many teachers don't have the confidence to admit their lack of expertise to their students. This leads them to stifle the student's ideas or only present them with them mediocre challenges. Links with the community's skills overcomes this and provides the best learning environment: a mix of student, curriculum and assessment learning connected to the community (Bransford, Brown, & Cocking, 2000).

In High School, the available technology, tools and teacher skills result in a more engineering approach. In 1991, King Edward VI School in Hampshire, England challenged their 14-year-old pupils to design and make a mechanism for collecting and disposing of dangerous objects (Figure 7) (Farley-Pettman, 1991).

Figure 7: Making sensors, making a platform, two example designs, testing, laying the site and collecting, transporting and disposing of the waste.

3.4 Curriculum and Assessment

The novelty of special events and research projects in schools conjures an excitement often missing from the humdrum of day-to-day school lessons. And while we can favour a constructionist approach to learning, you can't always take that approach under the demands imposed by the government's education policies. ERA's Curriculum and Assessment Principle recognise the ability of robots to support lessons using a constructionist approach under these restrictions. User Robots and maker task helps you do this (Figures 8) and Figure 9 the winner of a National Design Competition (Hudson, 1992).

Figure 8 (left): This number line task aims to help students understand equivalence. Making the robot into a delivery truck links the student's experience to the mathematical ideas. Figure 9 (right): Making the bird is a starting point, for the migration project: it inspired children to ask questions and prompted their investigations.

You'll notice in some examples maker tasks go beyond making a robot to creating an environment for the robots. These tasks play an enriching role in maker projects with User Robots (Figures 10) and (Figure 11) (Flint, 2013).

One unrecorded project took place in Wales in 2004. The challenge loosely based on the Baroness Emma Orczy's story, the Scarlet Pimpernel, saw the robot King Bot escaping from prison. The robot had to interact with an intelligent environment. King Bot autonomously made his way through a maze, triggered sensors to open a door, follow a line and lower a drawbridge.

Figure 10: 1990's Student in Norfolk, England made this village and robot cars with working headlights. They then programmed the robot to pass a driving test as part of a road safety lesson.

Figure 11: 2013 Maple Cross School, Rickmansworth - students created a version of Mos Eisley, the town with the cantina scene in the first Star Wars movie. The students made their own robot Star War movies which involved writing scripts and drama lessons. You can quickly add characters to the robot with designs based on stick puppets (right).

3.5 Personalisation and Practical ERA Principles

In the spacecraft rescue challenge students made a robot to recover a space ship crashed in a canyon. Figure 12 presents two solutions which show how you can tailor a challenge to suit the student's circumstances. While they're distinct, ERA Principles work together: in this case, we see the ability to adjust the task to suit the lesson time, tools available (Practical) and the student's age and ability (Personalisation). For her doctorate, Stephanie Holmquist repeated the challenge with Elementary schoolchildren in Florida - showing the adaptability of such challenges (Holmquist, 2014).

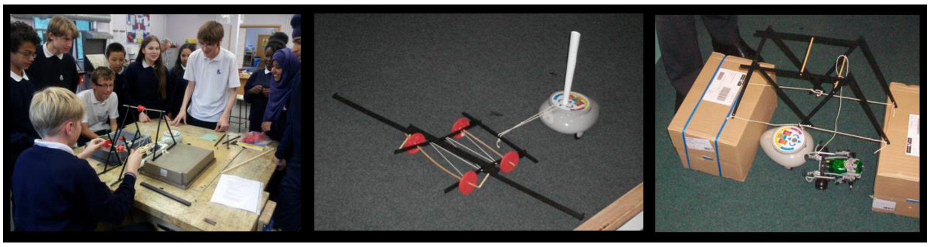

Figure 10 Kelmscott School STEM Club, Walthamstow, East London (left) had a workshop available and 90 minutes to solve the problem. The 18-year-old students from Wilson and Wallington Schools in Surrey, on a maths enrichment day (centre and right)' had 3 hours and minimal tools. They had to find the most economical solution based on material and manufacturing costs. The problem had three parts: a structure to help lift the spacecraft, a means of carrying it to safety and robot navigation. A Kelmscott team came up with the best idea - a forklift truck.

Making projects culturally relevance is another example of the Personalisation Principle (Figure 12).

Figure 11 Maori Robot Masks with traditional tattoo designs (Left); Squaxin Native American Dances with woven blankets (Middle); American Square Dancers from Illinois – another example of stick puppet designs (Right).

In the 1990s the Maori Council in New Zealand adopted Roamer as a technology they could use in a way to express their heritage. They programmed the robots to perform their stories. In 2010 Squaxin Tribal Elders in Seattle, Washington State approved a summer camp using Roamer. The students decided to program the robot to do traditional dances and wove blankets for the robot. At first, the Elders saw the project as an extension of school work, but this changed when children started asking them about the dances and how to do the weaving. They then saw the robots as a tool of culture (Catlin, Smith, & Morrison, 2012).

3.6 Modern Technologies

Modern technologies like 3D-Printing (Figure 14) and gadgets like Arduino, Raspberry Pie and MicroBit can increase the potential of User Robots in Maker Spaces. You use the programmable controllers in two ways. First mounting them on to the User

Robots to increase their technical capacity[1]. Second, using them to make an intelligent environment for the robot to explore and interact with. For example, you could add traffic lights controlled by MicroBit to the Norfolk Driving Test project. The children then program the robot to automatically obey the lights.

Figure 14 shows two 3D Printed examples of Roamer characters: Left CosmoBot developed by Anthrotronix in the USA for use with autistic children and right a car created by Valiant as a proof-of-concept.

3.7 Practical Issues

We found a practical issue plaguing design technology in Primary schools. Most teachers grasped, for example, the purpose of gears and how they worked; they found ways to explain the ideas to children. Yet, when students struggled to make gears work, the teacher didn't know how to help them. Pupils lacked the skills and suitable tools to mount the gears with enough precision to make them run properly. Worse, teachers didn't have the detailed engineering expertise to help them. This led to much frustration and confusion: children's sound ideas failed because of implementation issues. Build Robots like, Lego[2], sidestep this problem because their precise parts work together.

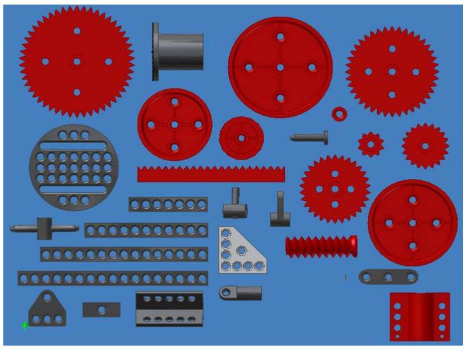

Figure 15: Inventa parts give strength, precision and connectivity to junk and recycled materials used in maker tasks. They speed up construction time: an important feature in a busy classroom schedule. Making them freely available for 3D printing will make them low-cost and improve the success of maker projects.

We did sell a system (Inventa), which overcame this problem by providing students with a set of precision parts designed to work with junk materials at a consummable cost (Figure 15). Just as an engineer wouldn't dream of making a bearing for a machine, they buy one from a bearing supplier, the students would use Inventa bits when needed. The children used some of these parts in the Fleet Circus Project (Figure 1). While we don't make these parts any more, we plan to make them freely available for 3D Printing.

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[1] The robots shown in Figure 6 achieve animation by adding a specially designed control box. Replacing this with gadgets like Arduino allows User Robots to maximise the use of kits available within the school (ERA Practical Principle).

[2] Lego Mindstorm's classifies as a (Type) Build Robot, (Class) Build System and (Subclass) Component Parts.

Around 2009 a small, informal group gathered at Tufts University to share ideas on education robots. One group presented plans to assemble a Lego robot, which students could use in an estimation task similar to the game shown in Figure 16. They claimed you could make the robot in 20 minutes. If the lesson aims to help pupils develop their estimation skills, most teachers would think this impractical. In this sense, User Robots have the advantage because students can start the main aim of the exercise immediately. If the teacher decides to make a robot character, it's for the reasons we've already discussed: they add value to the activity.

Figure 16: Target Practice helps youngsters develop their understanding of number, estimation, non-standard units and a simple introduction to coding. You don't have to add a maker task to User Robot challenges. Teachers do so to add value to an exercise or meet a specific curriculum need.

4 Conclusion

When most people think of education robots and the maker movement, they picture children making the robots from Build Robots like Lego or Vex. These popular approaches most often involve engineering and computing skills - which is just one part of the maker movement defined by Dousay. Some User Robots like Roamer and PIP, have over the years offered a convincing alternative more in-line with Dousay's ideas. Maker projects with these robots match the art and craft skills common among most Primary schoolteachers. Over the last few decades, efforts to add to the engineering skills of these teachers have met with limited success. Yes, you'll find plenty of individual success stories like those of Trevor Thomson and Alan Coode; but, most teachers don't venture out of their comfort zone.

While design technology and maker spaces have much in common, the focus on creativity and exploration in design technology has waned. I believe the maker movement and the use of User Robot Projects can revive it. Accepting the projects done with User Robots starts with Primary schoolteacher's existing skills and removes undesirable pressure. It means more teachers will willingly engage in maker tasks. I don't mean to abandon engineering designs, but follow Trevor Thomson's model and let the children's ideas dictate the need. Instead of a National Support Scheme, we should encourage schools to contact their local maker movements and other skilled people in the community. This approach creates the environment suggested by Branson. It won't transform teacher skills immediately: like all cultural changes, it takes time. If we let the student's creativity and imagination drive the projects and the assessment, we'll make positive, lasting changes.

Many robot and maker projects take place as special events outside the mundane schooldays. They produce high-energy, which gets squandered when students return to routine lessons. I've always felt this misses an opportunity; proper lesson planning should take advantage of the enthusiasm. I think this applies to all maker projects and deserves further research.

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