Robotic Performing Arts™ Project

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An approach to STEM through cooperation not competition

The popularity of YouTube and the low cost of video equipment make it a practical possibility for students to create movie-shorts. In the Robotic Performing Arts™ Project students make a video of something similar to a puppet performance, replacing the puppets with Roamer® robots.

This paper discusses the potential of developing the project as an alternative to robotic competitions. While robot competitions are very popular, this project offers an alternative approach to STEM[1] education where the main focus is on student collaboration and the connection of STEM and other subjects through the cultural heritage of the student community. The paper presents an initial raison d'être as a project starting point.

Pilot projects are planned with DATA[2] in the UK and MESA[3] in the Washington State. These aim to develop and evaluate these basic ideas and create a practical framework to support this approach. The results of these projects will be presented in future papers.

Keywords (style: Keywords)

STEM, Educational Robotics, Roamer®, Performing Arts.

[1] STEM: Science, Technology, Engineering and Mathematics.
[2] DATA: The Design and Technology Association.
[3] MESA: Math, Engineering, Science Achievement

Introduction

This paper outlines the rationale behind a STEM based educational program entitled Robotic Performing Arts™ (RPA). As part of RPA, students use the Roamer® robot system to create a movie. I will show that this involves a production process rich with creative opportunities to explore **S**cience, **T**echnology **E**ngineering and **M**ath (STEM) as well as other areas of the school syllabus. I will review the program from four different perspectives:

1. STEM Opportunity
2. Educational Issues
3. Robot Projects and RPA
4. RPA Program Outline

Valiant Technology is developing the RPA Program with various partners and schools in the DATA[4] in the UK and MESA[5] in Washington State, USA. As the project progresses, I expect to bolster this raison d'être through increased practical experience and research data.

Early Work

Southmead Primary School, Wimbledon, South London produced "Coodies Circus" in 1989 (Valiant, 1989). The students wrote the script and built the robots using Classic Roamer®. They created the scenery, programmed the robots and performed the voice-overs. In those days, making a video was literally a major production effort. The filming and film editing was done by a professional film crew. Now most schools own video cameras and editing software, allowing students to take over the video production tasks.

The use of stories with robots predates the Southmead work. Valiant Technology used contextual to support the use of their Turtle robot (Ginn 1985). Since then students and teachers have informally written and used stories as part of their regular use of Roamer®. New research advancing our storytelling and robotics methodology forms part of a parallel R&D Project (Catlin and Royce 2010).

STEM Opportunity

Performing Arts and STEM might seem an oil and water combination. This is far from the truth. Producing movies, stage plays, and even musical recitals and dance can require the solving of highly technical problems. The use of robots as the actors creates an environment rich in STEM opportunities.

One obvious STEM strand is the design and construction of robot characters (Jones 1991,

Figure 1 Roamer® provides a sculptural plaform for character creation.

[4] DATA – the Design and Technology Association is the recognised professional organisation representing all those involved in D&T education in the UK.

[5] MESA is a programs in several US states aimed at supporting disadvantaged and underrepresented students to achieve academically in math, science and engineering.

Valiant 1992, Catlin 2007). With Roamer®, this can involve anything from simple art and craft approaches, to the use of kits like Lego, Fischertechnik, or K'nex. In schools or colleges with well-resourced shop facilities students can design and make components to create unique robots. This adaptability makes Roamer® suitable for K-12 schools with wildly different technological capabilities.

In building a robot students manipulate the parts and so engage in exploring the principles of mechanics and structures, and their underpinning mathematical and scientific principles. They do this in a tactile, primordially practical and physical level. I think this is so important. Through the process of building a robot, you understand forces by seeing and experiencing their effects. You gradually develop an intuitive understanding of the mechanical sciences.

Once students have created the characters, they program them to perform their role within the performance. This involves synchronizing movement and action, which in turn involves a wide range of simple and complex mathematical problems. With Roamer®, students can program the robot using one of the Standard Keypads Modules (KPM) or the technically more complex PIC Programming methods[6].

The creation of a storyline for the RPA production has great potential to connect students to almost any topic and subject. For example, these Hollywood productions can engage students in scientific topics:

1. Star Wars — Space and space travel
2. The Impossible Journey — Human physiology and biology
3. Jurassic Park — Palaeontology

These fictional, even fantastical, movie plots contain a vestige of real science. How much science and how real is controversial. Some commentators hate the scientific inaccuracies (Rogers, 2007). I agree with the more sanguine, pragmatic stance taken by Professor Sidney Perkowitz (Perkowitz 2007) who discusses the trade offs between dramatic license and scientific principles, but points out that even though the real science may end up on the "cutting-room-floor", movies tend to appoint science advisors whose job is to get the best representation from the plot line. This creative, but realistic interpretation of science becomes the task of the students.

However, using artistic media to inspire students does not need real science as its basis. The Jules Vern story "Journey to the Centre of the Earth" may be impossible for humans, but could a robot be able to do better? Just answering the question engages students with real science. Leroy Dubeck at Temple College has pioneered some efforts in this area (Dubeck, et.al. 1993; Dubeck and Tatlow 1998).

I anticipate being able to adapt some of the approaches developed by these pioneers to make them applicable to the broad aims of RPA. But in general, when students become scriptwriters they control the realism of the science presentation.

Over the last few years, the deep connections between language and mathematics have become apparent (Lakoff and Nunez 2001: Paulos 1998). I claim that narrative is equally potent in all STEM disciplines. Through the careful selection of assignments, teachers prompt students into thinking about topics in and "out of the box". That is instead of learning to regurgitate

[6] Roamer® is a modular system. The KPM is one module, which can be configured to provide different programming environments (behaviors). The four Standard KPMs provide a scaffolded Logo-like environment. Through PIC programming the students create unique autonomous Roamer® behaviours. See www.valiant-technology.com

normative views, creating stories encourages students to make the ideas personally meaningful. And for the record, embedding information into stories is recognized memorization technique (Byron 2006).

In some preliminary work in this area, students wrote stories that embrace keywords from forthcoming study topics – for example speed, time and acceleration (Catlin 2010). The students' stories showed their naïve, intuitive understanding of these concepts and made clear what they misunderstood. This gave the teacher a grasp of the student's prior knowledge – a critical principle in the science of learning (Bransford et.al 2000). More interestingly, when the students tried programming Roamer® to animate their stories, they found their perceptions challenged or affirmed.

Educational Issues

Here, I want to talk about a few educational issues that RPA will address:

1. Interdisciplinary Teaching
2. Student Engagement
3. Equity

Interdisciplinary Teaching

For practical reasons the way we teach artificially splits knowledge into different subjects. Today many teachers recognize the importance of reconnecting knowledge into a holistic experience (Wood, 1997: Bolak, et. al. 2005). This has led to a rise in interdisciplinary projects. Roamer® is inherently a cross curricular device. The power of Robotic Arts is its ability to interconnect Roamer® to a wide range of subjects, particularly bridging the chasm between Science and the Arts.

Student Engagement

Engagement is one of the ten ERA Principles (Catlin and Blamires 2010). Engagement is the capture of the students' attention, transforming them from bystanders to an active participant. It entails ideas like motivation and recognizes that learning itself is generally an enjoyable experience that does not need "jazzing up" with gimmicks.

In 1997, students from the Fleet Primary School in Lincolnshire decided to create a performing arts project about a circus. They designed and made various automata for each act and performed a Christmas Circus presentation for their parents (Valiant 1997). Head teacher Trevor Thomson was instrumental in the whole process. This example displays some manifestations of engagement:

1. Students immerse themselves in learning
2. Topics of study follow student interests and enthusiasms
3. Teaching to test is abandoned
4. Learning becomes authentic
5. Students give up their time to the project: in school breaks and at home students took every chance to work on the project
6. Knowledge ceases to be isolated: it becomes interconnected to other topics in the same subject and across subject boundaries
7. Knowledge acquired through engagement becomes memorable
8. Knowledge is not simply a remembrance of facts; it also contains emotional content

These qualities apply to the engagement principle, whether Roamer® or the RPA project is involved or not. You cannot guarantee what will engage students. My claim is that Roamer® has a propensity to support engagement and its nature is to sustain and encourage the positive learning aspects that derive from this approach. I predict we can say the same about RPA program. Together Roamer® and RPA offer a strong possibility of engaging students in positive learning experiences.

I contend that most students who enter robotic competitions are already interested in STEM subjects. Since many of these projects form part of after school programs, they tend not to attract students with little interest in these topics. I expect the focus on performing arts will attract students not normally interested in STEM topics. This is not an attempt to "fool students into a math class". Instead, it is about providing the student with a new perspective on the subject. Ralph Llewellyn, University of Central Florida created a physics course based on movies (Llewellyn 2002). His course invitation captures the zeitgeist of RPA:

> *Physical Science is a course for liberal arts students who are seeking to understand the world they live in… …to revitalize the course and, hopefully, ignite in students the flame of passion for science through the study of films.*

Equity

Research and classroom practice show that minority pupils perform better when teaching is filtered through their own cultural experiences and frames of reference (Gay 2000). Combining Roamer® with RPA offers a way of achieving this through several mechanisms:

1. Robot ancestry links them to almost every culture in the world
2. Application of dramatic traditions to educational robots
3. Robots act as transitional objects
4. Culture and RPA share the same narrative foundation

Robot is a Czech word for work that has found its way into all the major languages of the world. The word, which means hard labor and serfdom, came to prominence when the Czech writer Karel Capek used it in his play R.U.R[7] (Capek 2006). A robot is an artificial person: a cheap source of labour.

The idea of artificial life has many antecedents in many different cultures: for instance the creation myths where life springs from blood, mud, sticks, or stone. In other stories, statues or machines come to life. Chinese, European and Arabic cultures developed traditions of automata.

Examples of Artificial Life in Various Cultures			
Creation Myths		**Statues that come to life**	
Creature	**Culture**	**Creature**	**Culture**
Mbongwe	Bantu	Pygmalion	Greece
Obatala	Yoruba	Tilomatta	India
Tawa	Hopi	Gesar of Ling	Tibet
Tepeu	Mayan	Kwha-Shu	China
Glooscap	Mik Maq	Talus of Crete	Greece

Puppets show another form of the human anthropomorphic tendencies that have evolved in most cultures. We do not restrict this process to artificial humans. We endow animals, trees, rivers, machines – we give all of them the gift of human-like-life. I believe that Roamer® is an

[7] Rossum's Universal Robots

extension, indeed a fusion, of this inclination with robotics. As such, I think it offers a potential bridge between heritage and modern education.

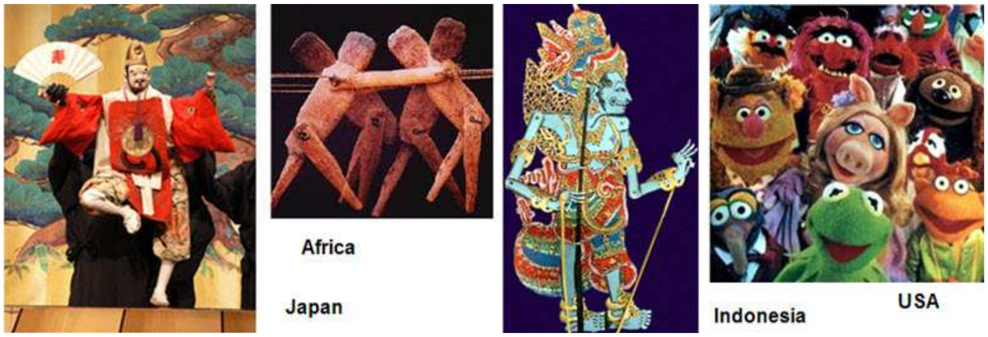

Figure 2 Puppets have a long tradition in most cultures.

Several lines of study offer themselves as ways we might use the insights of other disciplines to to develop and use robots within the RPA context. Western Dramatic theory starts with Aristotle Poetics (Aristotle 1997). He gets straight to the point:

> *Imitation is natural to men from childhood onward, one of the advantages of men over the other animals consisting precisely in this, that men are the most imitative of things and learn by imitation.*

Aristotle is talking about mimesis, the art of imitation. Despite its Eurocentric academic tradition, mimesis is the common denominator that runs through the cultural output of all societies. We add to this the related idea of verisimilitude, the techniques an artist uses to persuade the audience to suspend disbelief and embrace the story. Each culture has traditional methods for achieving verisimilitude (Bell, 2001) and it is a task of this project to study, explore and experiment with culturally responsive methods of doing this with educational robots.

While the foregoing remarks relate to traditional cultures, the analysis applies equally as well to contemporary cultures – for example Hip Hop. It applies to highly localized, dynamic cultural variations.

Studies of young children in Western cultures show the importance of transitional objects (Winnicott 1971) in the development of students' abilities to think about their world (Piaget 1962). These psychological mechanisms are not restricted to occidentals. Research in Papua New Guinea reveals the same imaginative and richly poetic process amongst Huli children (Goldman 1998). Papert referred to the original Turtle robot as a transitional object – an object to think with (Papert 1980). We normally associate transitional objects with small children. Originally, Papert thought of the Turtle in the same way. Later, he came to realize "what was good for thinking was good for thinking", no matter your age and no matter your level of sophistication (Papert 1983). We need to add substance to Papert's bold statement. We need to understand about transitional objects with older children and adults. This entire area needs more work, particularly regarding the practical exploration and integration of Activity Theory and Object Relationship Theory (Leiman 1999).

Robots created as neutral technological devices support the ERA Principle of Equity (Catlin and Blamires 2010). Roamer® is a tool and like a pencil, for example, it does not belong to a specific culture. It is a tool used by an artist in the production or consumption of cultural meaning (Hall, 1997).

Maori students used Classic Roamer as part of a RPA Project. They created Maori robots programmed to perform their traditional dances.

An American square dance version of the Maori project.

Figure 3: The design of Roamer robots can reflect the students cultural interests.

ERA compliant robots, like Roamer®, support these ideas. Roamer®'s amorphous shape provides a backdrop onto which students can sculpture a design that is an expression of themselves and their culture. It does not need to be high-tech or low-tech.

MIT's Edith Ackermann acknowledges the role of design as a means bringing the imagination into existence (Ackermann 2007). She makes the point made earlier by Schön.

> *…learning is designing, and designing is a conversation with – and through – artifacts. (Schön, 1983)*

While Roamer® provides an artifact with latent design capability; the RPA element brings an endless source of relevant problem solving scenarios. Together I believe they offer an environment rich in creative learning possibilities.

Roamer's link to ancestral origins provides one RPA cultural connection. Narrative is another. It is a potent factor in human life and child development and has particular relevance to RPA. Narrative is at the heart of a child's play. It is central to indigenous teaching practice (Peat 1994) and it provides a bridge that can link a student's cultural experience with the knowledge acquisition goals of the curriculum. In its broadest sense, narrative includes art, dance, movies, stories, plays, etc. Non-verbal forms of mimesis narrative precede language (Donald 1991). Yet narrative is the essential outcome of language. Narrative is the primary way we give meaning to our experiences (Polkinghorne 1988, Bruner 1987 and 1991).

Stories lie deep in the heart of every culture. The great Hindu epic the Mahabharata poetically tells the reader what to expect as the narrator summarizes the potency of the story:

> *Whatever is here is found elsewhere. But whatever is not here is nowhere else…*
> *…It's about you… If you listen carefully, at the end you'll be someone else.*

(Translation van Buitenen 1973)

Storytelling has an established role in modern education (Salans 2004; Gersie and King 1990). More recently, some researchers have experimented with storytelling and robotics (Druin and Hendler 2000, Stanton et al 2004). Others are currently engaged in combining all these threads into a new genre of educational robotics activities (Catlin and Royce 2010). RPA will draw on much of this work.

RPA enables students to play with STEM ideas, using robotics as an expressive medium, but from within the student's cultural and social milieu. If offers them the opportunity to understand concepts on their terms.

Robot Projects

Robot projects have become relatively common. For example: First Robotics - Lego League, BotBall, ROBOlympics, etc. Elements of these are:

1. Overtly STEM orientation (which does not appeal to everyone)
2. Focused on students building robots
3. Competitive in their nature

RPA focuses on cooperation and not competition. An RPA task list involves far more than a simple focus on STEM skills. It involves language arts, music, art, media studies, and arts and crafts. Nevertheless, embedded in these tasks is the potential for some *hard-core* STEM work.

- Creative Writing
- Storyboarding (Planning)
- Designing and making Robot Characters
- Set Design and Construction
- Creating Special Effects
- Create and Produce Musical Scores and Sound Effects
- Creating and Recording Roamer® Dialogs
- Filming
- Post Production

List of RPA Tasks

All the students involved in this project will engage directly or indirectly with STEM tasks. Hoever, even those who remain on the periphery of dealing with explicit technology will get the opportunity to see the value of STEM knowledge. This can be enough to reverse the normal *"Teach-Practice-Interest"* strategy. That is:

1. Teach methods
2. Let the students practice the taught methods
3. Try to persuade students what they've learnt is practical, useful and interesting

This is the wrong way round. It is far better to create the interest and engagement first.

RPA Project Outline

Schools are exceptionally conservative and very reluctant to move away from traditional approaches. There are many calls for innovative programs, but few educators are willing to embrace the systemic change needed to ensure significant improvement. I propose we investigate several ways of organising RPA. This gives schools the option of choosing an adaption that best suits their circumstances. The most obvious basic approaches are:

1.	Classroom Project	This is run as an ongoing project within the regular timetable. A theme is chosen from the curriculum. I would expect such projects to have their ambition curtailed by practical teaching issues. Nevertheless, they can still be valuable.
2.	After School Program	This provides an option for "going off curriculum", though it can be organized as a supplement to normal school work. Generally, we anticipate the scheme to be less formal.

For those willing to try major change I think the RPA offers a fascinating option: it can be run as an Inspiration Program at the start of the year. It should be a part of the regular timetable.

Sometime ago Valiant was working with a teacher who suggested some dates for a trial of project. The teacher commented, "… *these dates were good because the exams are over and **we're free to do the interesting stuff**!*" We need to be doing the interesting stuff all year.

Brophy suggests that our first task should be to focus on motivating the students to learn (Brophy, 2004).

The RPA project has the potential to provide an inspirational environment. It does this by changing the *"Teach-Practice-Interest"* model and starts with need and motivation. Generally, within a project, students discover something they want to do but do not know how to. This authenticates the learning scenario. The need for knowledge comes first. The solution becomes "cool". Once learnt, students take ownership of the knowledge and actively seek new scenarios where they can use their newly found wisdom.

Supporting and Managing a Project

The RPA approach tries to use best teaching practice as outlined by the science of learning (Bransford et. al. 2000 and Sawyer 2006). Trying to classify it using such labels as constructivism, constructionism, guided participation, instructionalism, etc. is problematic. These terms seem to be embroiled in an academic "storm in a teacup". Mayer for example claims that:

> *…there is sufficient research evidence to make any reasonable person sceptical about the benefits of discovery learning —practiced under the guise of cognitive constructivism or social constructivism….*
>
> *(Mayer 2004)*

When viewed through the eyes of practitioners like Trevor Thomson, Mayer's arguments appear to be of the strawman variety. He discusses the notion of "pure discovery" learning – a thing never found in Trevor's classrooms even though he would claim to be an ardent supporter of discovery learning.

The RPA approach requires teachers to be at the "top of their game". One aim of the program is to serve communities normally classified as disadvantaged. A challenge arises here because the quality and qualifications of teachers in these communities is generally lower than average (Darling-Hammond, 2005). A standard instructional design strategy to overcome these issues is to provide teachers with scripted responses to anticipated situations. Dylan William criticized this approach (William 2007). He pointed out that even the best-regulated classroom is still a chaotic place, only capable of description by Chaos Theory. Effectively you cannot prejudge the complexity of learning situations. Imperceptible differences in scenarios can cause the same intervention to be a miserable damp squib in one case an instigator of multiple epiphanies in the other.

This complexity highlights the difficulty in trying to endorse one teaching strategy over another. The various theories serve a purpose in suggesting options, explaining processes as they unfold, but I think it is impossible to train and support teachers to run RPA projects based on theoretical analysis. What we really need is to "clone Trevor Thomson". We need to study the way our best teachers work and find ways to pass this expertise to less experienced colleagues. I believe we can do this through the creation of online communities. Although this aspect of RPA requires a major study, at this stage we can highlight a number of criteria the system will need to address:

1. Project themes — Project themes need careful selection to ensure they have the latent potential to meet study objectives. Anti-constructionists perpetuate the myth that "students" choose to study what they are interested in. They do, ***but***, in practice the teacher "rigs the deck". The students at Fleet School chose to do a project on the circus. Trevor had planned that they would make that choice. The subterfuge makes a huge difference to the student approach to the project. Another way of looking at this is that the teacher's role is to motivate the students' choices.

2. Guide — Students will get ideas and enthusiasms. Again the teacher's role is to "manage" the process. In the circus project the Fleet students wanted to visit a circus[8]. Trevor took the opportunity to turn this into a writing assignment. Instead of visiting an evening performance, he suggested the students write to the circus, explain their project and ask if they could visit them during the day. A teacher, who had run away to the circus and become a clown, acted as their tour guide. Trevor set the next writing assignment as an essay: A day in the life of a circus performer. You cannot plan or script this kind opportunity, but you can learn to leverage it.

3. Support — Trevor Thomson is a confident and brave teacher. His students' imagination often dragged him out of his depth. They would ask questions that he could not answer, or they would want to do things he thought impossible. His solution to this was to enlist the help of his local community: if he did not know how to do something, he would find someone who did know. With our ability to build online communities through systems like My eCoach[9], this becomes a practical possibility.

Conclusion

This document presents the case for approaching STEM by utilising the ethnic traditions of communities. It has also lays out the work necessary to create such a programme. The challenge is to follow this path, not in a dogmatic fashion, but with openness and a clear focus on the needs of the students and teachers.

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[8] A circus was in the Fleet School area at the time – which was the hook that Trevor used to manage the students' choice of a circus as a theme.

[9] http://my-ecoach.com/

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