# 29 Effective Ways You Can Use Robots in the Classroom

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# 29 Effective Ways You Can Use Robots in the Classroom

## An Explanation of ERA Pedagogical Principle

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**Abstract.** Catlin and Blamires proposed the "Educational Robotic Application (ERA) Principles". These 10 principles give researchers, designers, educators and teachers a way of evaluating and comparing educational robots and their activities. The 'Pedagogical Principle' was one of these ideas. It stated you could use many different developmental theories to view and describe the learning involved. It also identified 28 (now 29) different ways you could use a robot in a classroom. Catlin and Blamires did not give a satisfactory explanation of the these methods. This paper corrects this.

## 1 Introduction

Blamires and Catlin wrote the ten Educational Robot Application (ERA) Principles to help understand the value of robots when used in radically different ways (1). For example, comparing how a robot aids a 4-year old understand number, with how they aid an 18-year-old to grasp vector analysis. The original paper did not fully explain the ERA Pedagogical Principle. This paper will resolve this issue.

The paper starts with a brief review of ERA, and a detailed summary on the Pedagogical Principle. It reviews some recent work by other researchers in this area and critiques their efforts before developing the ERA idea. This exposition shows the Pedagogical Principle has two strands: the developmental theories supporting the use of robots and 29 different characteristics of educational robot projects. The paper explains these traits and illustrates them with practical examples.

### 1.1 Data and Method

The data used to support this report is from the archives of Valiant Technology. They accumulated this over the last 33 years. It is a mixture of research projects like the UK National Turtle Project (2), doctorial and master theses (3) and (4). It includes conference papers (5) (6) (7) journals and books (8) (9) (10) and various reviews by educators and teachers (11) (12)[1]. This data is supplemented with evidence from formal

[11] These citations represent a small sample of the data available.

adfa, p. 1, 2011.

and informal interactions between Valiant Technology and its tens of thousands of customers.

The work took place with pre-K to Grade 12 children in 27 different countries, notably the UK, USA and Shanghai. All the work used either the Valiant Turtle or the Turtle-like Roamer. Most of the work took place in the school classroom, but a significant amount took place in informal learning settings like museums, after-school clubs or special learning events like the Big Bang (13). Students varied from those needing extra tuition to gifted and talented, as well as students with special needs.

Many people consider much of this data as anecdotal and as such not worthy of consideration (14). They will consider some of the references as old and out of date. They're wrong to do so. The validation of ERA and the Pedagogical Principle is persistence. A teacher telling you of their experience of using a robot in classroom, without the intrusion of researchers has value. This value increases if the anecdote is repeated again and again. This is even more so when this repetition occurs over several decades, from different locations and radically differing learning environments. This paper is an analysis and summary of this data.

### 1.2 The Robots

The Pedagogical Principles comes from experience with Turtle Robots. The first of these is the Valiant Turtle, first produced in 1983 and controlled by the programming language Logo. The next robot is the Classic Roamer, first produced in 1989: students program this using its on-board keypad and chip based version of Logo.

The current Roamer started production in 2012. You can configure this robot in different ways, which enables it to support the educational need. For example you can change keypads and the behavior stored in the chip. You can program this Roamer with a keypad, or from the computer using Logo, Scratch or any other programming language. Indeed, you do not need to program the robot, you can make it work using Human Computer or Human Robot Interface technologies.

You need to make a distinction between Turtle robots and construction robots. The teacher can use Turtle within a few moments of the lesson starting – you do not need to build it. Turtle robots focus on "Teaching with Robots (TWR)" and construction robots on "Teaching Robotics (TR)". However, students can change the design of the Turtle and once built, teachers can use construction robots to teach ideas. While the data comes from using Turtles, an informal review of research papers shows the Pedagogical Principles applies to both types of robot.

## 2 ERA Principles

The ten ERA Principles comes from a meta-analysis of the work described in the Method and validated by their persistence. ERA refers to physical robots (**embodiment**) that children **interact** with. The robot has an internal **intelligence** or behavior that involves students in **personalized** learning experiences. Work with robots form an **equitable** learning environment where students **engage** with **curriculum** objectives in a way that develops their sustainable learning skills. Teachers must find using the technology **practical** in a busy classroom. The Pedagogical Principles connects all of this to the science of learning and describes the characteristics of robotic activities.

## 3 Educational Robotics Café and Important Thoughts

A workshop called the educational robotics café took place at the at the 6th International Conference on Robotics in Education (May 2015, Yverdon-les-Bains, Switzerland) (15). The group running the workshop aimed to take advantage of the conference expertise to find out an "overview of the educational robotics landscape".

The workshop lasted 3 hours. A report on the workshop outcome stated: "... *difficulty presented itself in finding common elements that made sharing or comparing possible. The approaches presented in the pre-phase were not described in that way. It would have helped, had they been broken down into elements that many approaches or activities have in common."* The Pedagogical Principle deals with this issue. It contains a list of basic "elements" that we can combine in different ways.

I disagree with one conclusion of the Café participants: "*In pre-school and elementary, children use a lot of imagination, thus robots have to be contextualized (e.g. using story telling). In junior high school, students use robots as tools to learn different concepts; in senior high school, the focus is building (mechanics and electronics) and coding "real" robots."* Characterizing the use of robots in this way builds unnecessary barriers that lessen the educational potential of robots. Why do we want to limit imagination to young children or building robots to older students? While this is common in contemporary practice, counter examples show it is not a valid premise.

It is a time for vision. Trying to describe a landscape based on survey of current practice and today's technology will not succeed. ERA defines a set of simple axiomatic statements, that will not change when innovations appear. They provide an analytical set of tools, but they also provide a guide for developers.

Catlin and Blamires did not simply review the decades of evidence available; they also looked at technological trends in subjects like AI, robotics and computing. A more subtle issue sneaks into the discussion – our current obsessions with STEM, coding and even robotics. Anyone who has survived the education sector for a few decades will know that in 5 or 10 years times we'll be chasing new educational panaceas. Initiatives, come and go, often inspired by technological advances. The ERA Principles needed to look beyond the current trends.

## 4 ERA Pedagogical Principle

ERA defines the Pedagogical Principle as, *"The science of learning underpins a wide range of methods available for using with appropriately designed educational robots to create effective learning scenarios."* This notion splits into theory and application. The original paper adequately explains the theory. While it recognizes the original connection to Piaget's constructivist ideas of learning, it takes a more eclectic view. Catlin and Blamires recognize all theories describe a learning process from a particular perspective. Therefore any theory is valid if it helps develop better robots or robot activities. Better means they help students to learn more, gain deeper understanding, learn faster, remember longer and enjoy the experience.

### 4.1 Application

The Pedagogical Principle is applied through activities. The Principle identifies 29 traits which characterize an activity. This paper proposes these form the basis of a Pedagogical Tagging scheme.

You can use the characteristics in two ways. First to help understand the nature of an activity and second to help design tasks. It's easy enough to think of an exciting robot challenge, but not so simple if you want to meet ERA's Curriculum and Assessment Principle. This principle ties work with robots into helping teachers deliver the curriculum and assess the effectiveness of the student's work. The "Backward Assessment Model" is an important instructional design approach (16). It starts with knowing how you plan to assess the student's work against a learning objective – what evidence do you want to gather. What activity will allow you to gather that evidence. The Pedagogical tags make it much easier to come up with good ideas when you've specific learning objectives in mind. Valiant used the tags over the last 10 years to help develop over 350 activities. They've used them for the last 5 years to tag and describe activities and correlate research in their e-Robot project (17). This longitudinal study is helping to refine and validate the tags.

### 4.2 Tag Candidature

A tag is a characteristic of the activity, independent of who, what, where and how the activity is done. In deciding if something is a tag it is necessary to remember that the Pedagogical Principle is one of ten ERA Principles. So for example is the gender structure of a group doing an activity a tag? The answer is no, because the activity and a tag is the same whatever group does it. (The gender issue is dealt with in the ERA Equity Principle). On the other hand problem solving is a tag, because in this context it is not a variable. Should we consider "fun" a candidate? Again no. You can do an activity with a group of students who find it great fun and others who do not. This has nothing to do with activity, but a complex of personalities, transient feelings of participants and many other factors. Besides, fun is a subset of the more powerful ERA Engagement Principle. Engagement is about the student giving their attention, whether it is fun or not. While Engagement is a separate principle it is included as a tag, because some educators did activities with the sole purpose of engaging the student. This illustrates another thing about this list, it is derived "bottom up". A candidate does not have to fit into Bloom's taxonomy or any other structure. What validates a candidate is that it is useful (ERA Practical Principle) and its persistence. That is you look at the 3 decades of data the same ideas appear time and again irrespective of the circumstances. You can deduce the list is not new. By 1990 most of the tags were in use. This paper is merely formalizing the list and acknowledging the activity characteristic has the value of persistence.

### 4.3 The Activities

Teachers devised most of the activities used to illustrate the tags. Yes they could have used different methods without using the robot. They choose not to. They choose to use the robot because of the reaction they get from children. One young woman reminisced about her school days, “I always knew we were in for a good day when the teacher got Roamer out.” This reaction related to the ERA Principle of Engagement. It is enough to justify using a robot.

### 4.4 The Tags

What follows is a definition and brief explanation of the tags, illustrated with an example activity[2]. The activity title is formatted in bold.

**1. Catalyst.** Using a robot to make an exciting start to an activity. In most activities robots play a “starring role.” However, they can make a useful cameo appearance. In the Roamer Activity: **Going to the Seaside** the students engage in a murder mystery game (18). A salmon is trying to swim to the sea, but keeps meeting pollution points which gradually slow it down until it eventually stops dead. Working in groups the students solve the pollution problems enabling the fish to make its journey. The robot dramatically captures the students’ attention by simulating the salmon’s fatal journey. If the students resolve the pollution problem they get to reprogram the robot and they can watch the salmon successfully swim to the ocean.

**2. Challenge.** These are small-scale problem solving tasks. You can characterize challenges as closed (one solution) or open (many solutions). Programming Roamer to navigate a maze is a traditional Logo exercise. In the challenge **Escaping Baron von Bugbyte** students programmed the Valiant Turtle to escape the evil Baron by navigating their way through a rabbit warren. It is a closed challenge – you escape or you do not. Good challenges have multi levels to them which allow you to personalize the challenge to the needs of the student. For example allow step-by-step programming or insist the students work out and program the robot in one try. Navigate the maze using left turns, or right turns only. Make the robot autonomous and use sensor to find a way through. **The Red Arrows**[3] challenge involves students programming several robots to move in a synchronized pattern. The students choose the pattern – which makes this an open challenge.

3. **Coding.** Papert invented the Turtle robot to provide a physical representation of the effect of coding using the LOGO language. The basic idea of LOGO was for students to learn mathematics by coding a computer to solve math problems. This

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[2] All the activities are subject to subject to the Creative Commons Licence . The citation should clearly state “This is an adapted Roamer Educational Robot Activity from Valiant Technology Ltd.

[3] The Royal Air Force’s display team.

involved students thinking about the basic structure of mathematical problems. LOGO branched out beyond mathematics and the recent interest in coding and computational thinking has revived the ideas behind LOGO. In the activity **Mondrian** program Roamer to draw Mondrian style paintings. This involves looking at a design style through the computational thinking patterns like procedures and repeats (19).

**3. Conceptualizing**. Robots help students understand ideas through concrete experiences. This is one of Papert's basic ideas. He saw a Turtle as a transitional object: something you can identify with. You can play Turtle by imagining yourself as the robot moving and turning: and while you do this, you're connecting to powerful mathematical and scientific ideas. Many people mistakenly think this class of application is for young children, but Papert realized that, "What's good for thinking is good for thinking" – irrespective of your age or ability (20). It is worth reminding ourselves of Einstein's many famous thought experiments where he imagines he is an a light beam travelling at the speed of light. I have conducted informal experiments asking several-hundred adults asking them "What is the answer four minus, minus three?" Only 5% have correctly answered 7 and none have answered why. Yes, they can answer something like two minuses give a plus, but why does this rote learning rule work? Teaching student's to understand is a Functional Theory belonging to the science of learning. Knowing the rule helped me pass an exam, but it did not help me understand the math. Indeed, it confuses: "two minuses" is mathematical nonsense. Minus is a math operation called subtraction and negative three is the name of a number symbolized as -3. **Conceptualizing Negative Number Arithmetic:** students use the robot to move up and down a number line which includes both positive and negative numbers. Forward means addition and backwards represents subtraction. As they do this, students start to understand the ideas involved.

**4. Cooperative Task.** These tasks focus on students working together. Cooperation is one of ERA's Sustainable Learning Skills. These skills form an intrinsic part of work with educational robots, for example projects involve students doing different tasks to achieve a common goal. However, cooperation is an incidental benefit, while in Cooperative Task it's the main aim. **Journey to the Stars** involved 5 students with behavioral problems. Getting them to work together on the smallest task was a major achievement. The group program Roamer (a spaceship) to visit various planets. Each member has a set of instruction cards and they can only achieve their goal by sharing their instructions. These students found it a struggle to agree, but gradually with some inspired guidance by the teacher they succeeded. In follow up conversations several students admitted they'd enjoyed the result and felt they could apply what they learned to improve their lives.

**5. Creativity.** Work with educational robots often encourages students to develop their creativity. We say you're creative if you produce a new perspective on the world. We often associate creativity with the arts, and ignore the feats of science, mathematics and engineering. Robots belong to both arts and sciences. **In the Doghouse** students make Roamer into a robotic dog and then program it to behave like a dog (21). If you were a painter you would create an image that when people looked at it, they would think – dog. Of course, as René Magritte's shows in his famous painting, "This is not a pipe" it is a picture that makes you think of a pipe. The robot dog is a robot that makes you think of a dog. One child made a tail out a moderately stiff rubber, they programmed the robot to wiggle so it looked like a dog wagging its tail. While many students programmed their dog to sniff around "trees", one child programmed the her canine to chase its tail.

**6. Deductive Thinking.** Students deduce ideas from their experience of using the robot. The Total Turtle Trip theorem came from Papert's invention of Turtle Graphics - a geometry which describes a robots movement in space. The theorem states the total amount of turning a robot does when traveling around a closed shape is always equal to 360 degrees. So the journey around a 'L' shape is 5 right turns and one left turn of 90 degrees: a net sum of 4 quarter turns in a right direction. In the Total Turtle Trip task the students send the robot around the perimeter of some closed shapes (22) As a deductive thinking task you expect the students to discover this Total Turtle Trip rule.

**7. Demonstration.** In a demonstration students react to a robot. They cannot influence it. In **The Sunbeam Traveler**, Roamer plays the role of a sunbeam traveling from the center of the solar system and visiting each planet. You place pictures of Earth and sun on the floor of a large hall. Students take pictures of the other planets and stand where they think the sunbeam will stop. They never guess correctly, but they get an emotional charge as the robot gets near their planet before passing them by. Normally they become awestruck at the distances involved.

**8. Design.** This is the province of robots like Vex and Lego, but some Turtle robots, like Roamer, allow students to create designs. In the **Hazardous Spherical Objects** students designed and made a robot for collecting and disposing of waste objects (23). While you can connect Roamer to kits like Lego and Fischertechnik, you can also use methods from the Maker Movement. In the early 1980s British schools created a subject called design technology. This involved using junk materials and basic tools to make wonderfully inventive machines it embraced many of the ideas now included in the Maker Movement.

**9. Engagement:** You apply this to activities whose primary purpose is to engage the student. Engagement is an ERA Principle, but that refers to the general nature of robots to attract pupils. **The Chicago Story**, is an example where a US teacher worked one-on-one with a problem student. His home life was a disaster and this reflected into his experience of school. The teacher introduced him to Roamer and started to explain how to program it. She asked, "How much do you want to make it turn?" He replied, "I want to make it turn all the way around," and he tried the instruction right 4: the teacher said "He was visibly shocked when it only turned 4 degrees." But the experience had him hooked. She reported that for the first time in his life he engaged with mathematics and in a 45-minute session he discovered the magic number 360. Before this he had never used double-digit numbers.

**10. Experience.** Robots can help students build learning foundations based on experience. Papert said, "That experience is at the heart of Piaget's real message, knowledge built on experience." When 2 years old Papert became fascinated by gears, he learned how they worked and what happened to one when you turned another (24). This helped the teenage Papert, to understand equations with two variables. Many of his friends who lacked his gear background struggled with the math. Papert's stated an educational researcher would not have noticed this key psychological moment. The science of learning now recognizes the importance of prior knowledge. In the **Pizza Delivery Roamer** the robot is working on a number line. The students program the robot to deliver Pizza to some of the houses. "Does the delivery order matter?" Students use the robot to explore and then explain the problem. Normally, you do this activity with students younger than 7, but they do not need to know, they're dallying with the mathematical idea of equivalence. There's no need to tell them, but they will subconsciously store the experience for future use.

**11. Experimentation:** You perform an experiment on how the robot behaves and you use that data to solve a problem, puzzle or challenge. In the Robot Rally Race students test how fast Roamer travels over different terrains and they use that data to calculate the fastest route around the rally course (6). They then test the results.

**12. Exploration:** We use the robot to explore and discover the knowledge hidden in a Microworld. This exercise adds excitement to primary school history lessons. For example Roamer is an **Archaeologist** and it starts to explore an Ancient Roman Site. Pupils program Roamer to explore the site. They discover artifacts and patterns that tell them whether the site was a marketplace, a barracks or a Roman bathhouse.

**13. Focused Task:** We use a robot to help students understand a specific learning objective. In **Understanding Fractions** we use Roamer to help students grasp key ideas about fractions. In Part 1 we ask the student to program the robot to move forward a distance 4 times. We mark the stopping points and discuss each step is a quarter of the whole distance traveled. In Part 2 the students repeat the first task but the robot moves forward a different length. In Part 3 the robot moves based on time on not distance. In Part 4 we ask the students to program Roamer to travel along a path and split it into quarters. However, the path is not straight: Roamer has to turn. Should they use time or distance? Will they get different answers? You can repeat the activity based on different fractions for example: halves, fifths and thirds. Part 1 shows students an idea, part 2 consolidates it, part 3 extends it and part 4 challenges the student's understanding.

**14. Games**: We use the robot in a competitive challenge between teams or indi-vidual players. In the Quizzer game we place Roamer in the center of an obstacle course which has two goals (6). The teacher asks a question and the first team to answer correctly wins a randomly chosen instruction card. Rules govern collecting, playing or stealing instruction cards. Playing the instruction card means programming Roamer to move towards your opponents goal. The first team to score wins. We've found playing this game at the end of a semester an excellent way to test student's knowledge about work they've covered that term. It adds excitement and engagement to a question and answer session.

**15. Group Work:** Students work with a robot in a group. UK Primary Schools organize students in groups of 6. This gives you an ideal working environment for use of robots like Roamer. Students will work together, discuss ideas and inspire each other or criticize in a way teachers cannot. Like the ET Movie, in the **Little Lost Roamer** the robot is an alien lost on Earth. How do they communicate with it? The students invent a body language that enables the robot to tell people whether it is happy, sad, frightened, hungry and so on.

**16. Topic Work[4]:** When teachers organize lessons around topics, robots can contribute. **The Great Fire of London** is a topic studied in all English Primary Schools. If you search the Internet you'll find plenty of teacher made resources on this topic. They include lessons in English, history, math, art, science and so on. In the Roamer task the robot is a fire ember jumping between the closely packed medieval buildings. This simulates how the fire spread from Pudding Lane and burned down nearly 90% of London's homes. Children program the robot to spread the fire to as many buildings as possible, while others find ways of stopping the robot arsonist destroying the city. This ties the children into thinking about how fire spreads, what materials burn and fire safety.

**17. Inductive Thinking**: Students develop a theory and test it. One of Papert's core ideas is that children develop theories about the world without any help from adults – it's simply what humans do. Of course not all their theories are correct, but, any theory, right or wrong forms part of learning. Papert calls these transitional theories. The Turtle gave students an object to think with – a tool that they could use to create and verify their ideas. In **Negative Number World** you set up Roamer to simulate arithmetic with negative numbers. The robot keypad has both positive and negative numbers and instead of forward and backward you have plus and minus keys. When the students explore the robot they form theories which they can then test.

**18. Links:** You can use these robotic tasks to link several ideas. Roamer offers endless opportunity to present problems in exciting ways and the links approach shows students how ideas interconnect. In the **Adventures of Myrtle the Turtle**, the robot travels back in time and invents geometry (25). The time traveler teaches a caveman to measure so he can build a bridge across a river. Then Myrtle showed the Egyptians how to draw squares and triangles, enabling them to build the Pyramids. She then taught Pythagoras about polygons and Archimedes about the circle.

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4 In the original list this class of activity was called curriculum.

**19. Memorization.** This theory states that robots can help students memorize facts. This is a theory I am currently testing. There are a few brain based theories on memorization. The “Method of Loci” or the “Memory Palace” methods come from around the first century BC. They’re published in a book by an unknown author on rhetoric called “Rhetorica ad Herennium”. It is still a technique used by 8 times World Memory Champion Dominic O’Brien, who calls it journeys[5]. The basic idea is it easier to remember if you attach your memory to the location on a journey. This seems ideal for Roamer. The **Tour Guide** task involves students programming the robot to take visitors on a guided tour of facts. If the theory proves correct the students will do better at recalling the facts.

**20. Modeling:** You can use robots to model ideas. Follow That Curve uses graphing software like GeoGebra to create a graph, which controls the motion of the robot. Students can see what a graph means by watching it move Roamer. They can experiment and see how the robot responds to changes they make to the graph. Once again the value of the robot is giving students concrete meaning of abstract mathematical ideas. Other modelling scenarios exist which robots have a role to play.

**21. Pacifier:** Educators have used Roamer to overcome student’s bad temper and resistance to learning. Roamer is both simple and neutral. In a **Cranial Trauma** case study Professor Christian Sarralié reported the case of an adolescent student who had suffered brain damage in a car accident (26). He had lost the ability to do basic math and became aggressive when teachers tried to reteach him basic arithmetic. Eventually, his teachers gave him a Roamer task, which needed simple addition. He then realized is problem, relaxed and became teachable. Roamer has a history of use by teachers working with students whose behavior means they cannot work in a customary classroom setting. They normally work one-to-one with special tutors.

**22. Presentations:** Students use robots to present their work. My work using Assessment for Learning methods shows presentations create opportunities for peer assessment. In, **On the Buses**, students design bus routes and time tables, which they model with Roamer (27) (28) . They used the robot to present their solution and explain their thinking. Other students had worked on the problem asked insightful questions in what turned out to be a lively debate.

**23. Problem Solving.** Robots provide excellent opportunities to engage students in problem solving tasks. Educators recognize problem solving has much to offer education. I use the term problem solving for complex problems and challenges for small-scale simple problems. In **Supply and Demand**, students use the robot to redistribute tea, coffee, milk and sugar between 4 cities. The problem has different levels. You can start students programming the robot to get equal amounts of each commodi-

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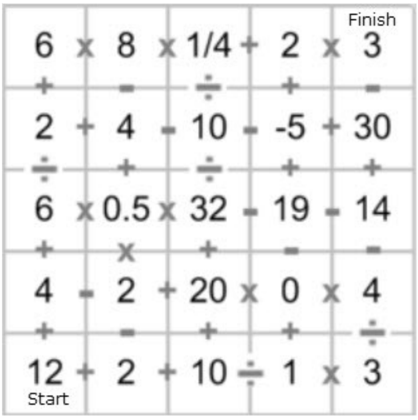
[5] Personal communication.

ty in each city. You can gradually make it more complex by adding time constraints and limits to how many commodities you allow the robot to move at any one time. Finally, you ask the students to model a business whose aim is to make profit.

**24. Projects.** I reserve the word projects for tasks that take several weeks to complete. Students work on projects as a team, but they often work independently on different parts of the project which they need to bring together. The Oxon Hill Middle School Peace Pledge is a **Robotics Performing Arts™ project** (29) (30) (31) (32). Students write the script for a movie, create the characters and sets for the film. They program the Roamer to act out the parts, film it and edit the movie. Although the robot is central to the project, not all the project team, such as the video editor, work with the robot.

**25. Provocateur.** You use a robot to provoke students into thinking and discussing an issue. A catalyst starts an activity, but your aim with Provocateur, is to get the students into a discussion. In, **"What Number is This?"** the robot moves up and down the number line telling the student the name of the number it stops on. It then starts asking the students to name the numbers. When the robot moves off the line to a number like 12 it provokes a discussion. The students know the names of numbers higher than 9 so they can answer the question. You provoke a bigger debate when Roamer moves to a negative number and asks, "What Number is This?" When I've tried this activity students eventually suggest "adding numbers going the other way". In other words, they invent negative numbers.

Figure 1 Biggest Number Grid




**26. Puzzle:** You can use educational robots to solve a puzzle. The dictionary defines a puzzle as, "a toy, problem, or other contrivance designed to amuse by presenting difficulties to be solved by ingenuity or patient effort". They're usually abstract problems, where it is normal for a challenge or a problem solving task to have a context. In the **Biggest Number** (Fig 1) students write a program that will move the robot from the start to the finish around a 5 x 5 matrix (13). Each cell of the matrix as a number and the robot picks up a mathematical operator depending on how they arrive at the cell. They can only visit a cell once. The highest score in found to date is a remarkable 760,230.

**27 Relational Artifact.** People form bonds with objects and evidence shows they form special bonds with robots. I talk about this in detail in the ERA paper. Sherry Turkle reports experiments with students and seniors who interact with robots as though they were living creatures. Turkle cites examples of children reveal deeply held concerns that affect their lives (33) (34). I have direct experience of this. Teachers over-heard a young girl talking to Roamer and realized somebody was abusing her. You can use this in a positive way when introducing children to a robot. **Getting to Know You** introduces young children to the robot and teaches them how to look after and program it. I believe this principle has a lot more to offer in the future.

**29. Transfer:** Transfer happens when you apply knowledge gained in one context to another. This takes place in three ways. You learn something in class, and use it with Roamer. You learn something with Roamer and use it in class. You apply a Roamer lesson to a different Roamer challenge. We tag tasks that use these methods as examples of transfer. The sequence example, consolidate, extend and problem solve involves transfer. You can for example follow up Understanding Fractions with non-robotic work on fractions or you can do it the other way. In Plough the Field students study medieval agriculture. They learn how Imperial Measurement (miles, furlongs, chains, yards) came from this farming activity. The students write programs using repeat commands to simulate the process. In **What's That Tune** students adapt the same mathematical and programming skills to programming the Roamer to play music.

### 4.5 Using the Pedagogical Tags

You need to use several tags to describe an activity. It is important to write the main tag first and then add others. It is essential you develop consistency. Table 1 lists a few examples taken form section 4.2.

**Table 1.** Examples showing the use of multiple Pedagogical Tags.

| Activity | Main Tag | Other Tags |
|---|---|---|
| In the Doghouse | Creativity | Design, Inductive Thinking, Presentation |
| Biggest Number | Puzzle | Focused Task, Game, Engagement |
| Robotic Performing Arts™ | Project | Design, Group Work, Links |
| Pizza Delivery Roamer | Experience | Modeling, Inductive Thinking, Challenge |

## 5 Conclusions

This paper clarifies details of ERA's Pedagogical Principle. This has two parts the first about developmental theories and the second to a Pedagogical Tagging Scheme. This scheme identifies 29 tags which we can use to characterise educational robotic activity. The value of developmental theories lies in their ability to help design better educational robots and better activities. Better means the capacity to help students to learn more, gain deeper understanding, learn faster, remember longer and enjoy the experience. The tagging scheme describes fundamental nature of an activity irrespective of how, where, when or who uses the activity. The tags do describe the basic nature of an activity in an abstract way.

## 6 Acknowledgements

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