Elementary Engineering Curriculum (EEC)

John Heffernan, Williamsburg Schools

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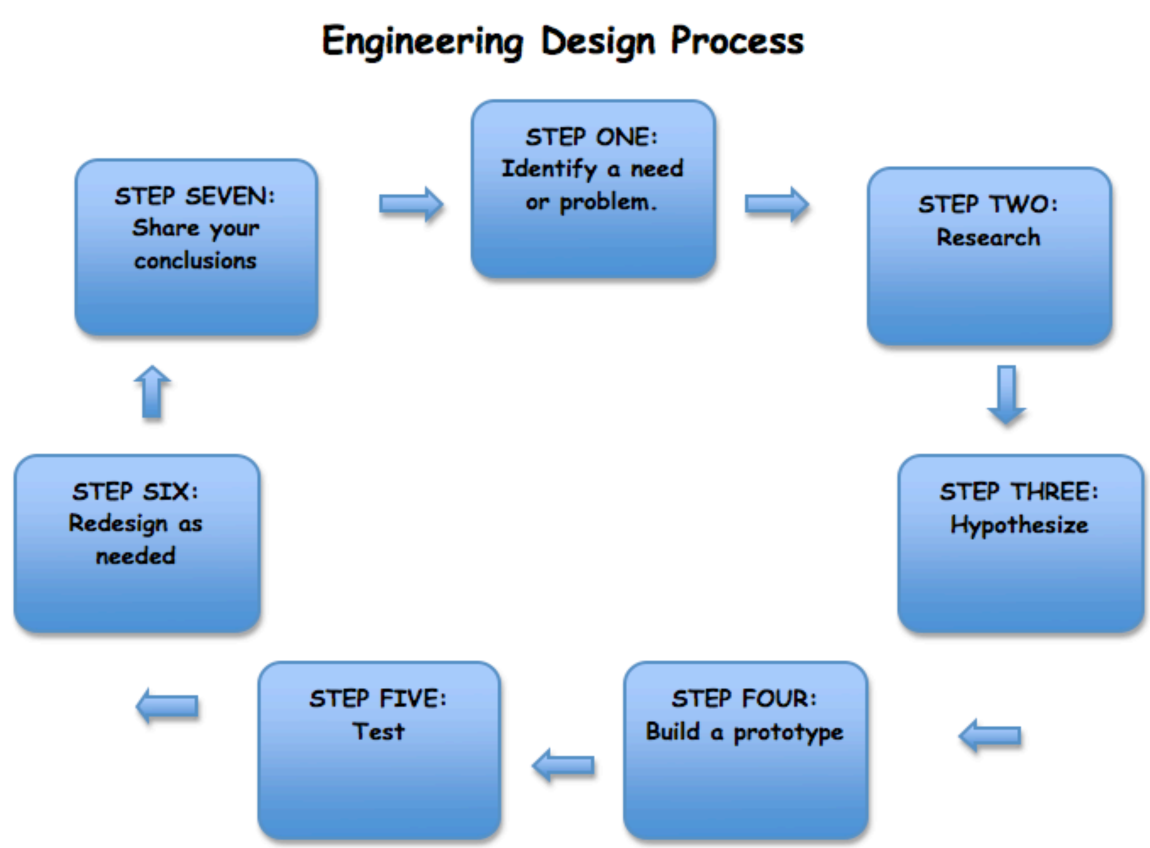
Project Summary

The goal of the EEC (double E C) project is to create a PK to grade 6 engineering experience based on robotics. Each year, students will have at least one robotics experience. In grades K, 2, 4, and 6 students will also have an open ended engineering challenge. We will explicitly teach the engineering design process as appropriate to the grade level.



The project will start at all grades simultaneously. As the project progresses, we will sixth graders with 1 year of engineering experience in year 1, 2 years in year 2, all the way up to 8 years in year 8. We will capture artifacts from these challenges and compare them by both years of experience and longitudinally (looking at individual students' progress over time.) We would expect that students will improve in their engineering design skills but this also presents a unique opportunity to see how they improve and how attitudes about engineering change.

There are many reasons for introducing engineering to students early in their academic experience. First, students will need 21st Century skills for successful careers. These skills differ from skills traditional taught in schools. The Partnership for 21st Century Skills [need citation] defines the 4 Cs - communication, collaboration, creativity, critical thinking – as critical needed by our citizens in the future. Second, the EEC is very rich not only in engineering but in science, math, and technology. English Language skills are also used in the curriculum. Third, the EEC will benefit both girls and boys. We have seen many boys that may be struggling with reading and attentional issues really shine when it comes to robotics. For the first time, they are seen as leaders in the classroom. Additionally, girls that may not have had experience with Legos will be gain experience with engineering and building with Legos. Research [citation needed] shows that we can not wait until middle school and high school to expose girls to engineering. Finally, robotics is a very high interest, motivating, and deep experience for students. Their level of understanding is much deeper when actually using and building these machines. [citation needed]

Typically, early elementary students have few, if any, engineering experience. The essential questions of the EEC project is: how would students look if they received engineering education from grades PK to grade 6? Although we hope the project will contribute to the pool of talented STEM workers in the future to maintain US competitiveness, we believe engineering to be a valuable way of thinking that will benefit all. In today's media environment, many citizens have trouble distinguishing facts from opinions and also have difficulty with complex scientific theories. Engineering provides a clear way of testing hypotheses, doing research, and determining objective measures of physical processes. In summary, the EEC project will teach valuable skills in engineering and many other subjects in a fun and deep way.

Engineering and Robotics Scope and Sequence

Grade /Lesson	Lesson	Platform	Subjects	Materials/Notes
PK.0	Free Explore	BeeBot	Technology	
PK.1	Counting	BeeBot	Technology, math, engineering	Number lines
K.0	Line Following	BeeBot	Technology, engineering, math, cooperative learning	Students program the BeeBopts to follow some letter shapes made from tape on the floor. Some letters require backtracking.
K.1	Addition	BeeBot	Technology, math	Number lines. Students teach their BeeBot to add using a number line.
K.2	Subtraction	BeeBot	Technology, math	Number lines. Students teach their BeeBot to subtract using a number line.
K.3	Pause/Cross game	BeeBot	Technology, engineering	Tape. 2 teams of 2 team up to cross the street safely. Students use the pause button to wait until it is safe to cross the street.
K.OE	Best Path Engineering Challenge	BeeBot	Technology, engineering	Tape, blocks. Story context: the bees need their honey but something is blocking the way. Help the bee find its honey.
G1.0	Getting Started - Gears	WeDo	Technology, engineering	
G1.1	Getting Started – Pulleys	WeDo	Technology, engineering	
G1.1	Dancing Birds	WeDo	Technology, physical sciences, cooperative learning	

G2.0	Smart Spinner	WeDo	Technology, physical sciences	Clock(s)
G2.1	Drumming Monkey	WeDo	Technology, physical sciences	Cups or yogurt containers
G2.3	Hungry Alligator	WeDo	Technology (sensors)	
G2.OE	Engineering Challenge	WeDo		Invent your own amusement park ride.
G3.0	Airplane Rescue	WeDo	Technology, literacy	
G3.1	Giant Escape	WeDo	Technology, literacy	
G3.2	Sailboat Storm	WeDo	Technology, literacy	
G4.0	Goal Kicker	WeDo	Technology, math	Different teams will do one of the soccer robots and then have a game with the other teams.
G4.1	Goal Keeper	WeDo	Technology, math	Need ping pong balls for all 3 projects
G4.2	Cheerful Fans	WeDo	Technology, math	Cheerful Fans is the most difficult and the Goal Kicker is the least difficult.
G4.OE	Engineering Challenge	WeDo	Technology, engineering	Design a burglar alarm. Encourage the use of both sensors and the motor.
G5.0	Basic car	Mindstorms	Technology, engineering, cooperative learning	Students build the basic NXT car.
G5.1	Line Following Without Sensors	Mindstorms	Technology, engineering, math	Tape. Students program their car to make a square and to follow some taped paths.
G5.2	Sound Sensor	Mindstorms	Technology, engineering	Students program their cars to stop when they hear a sound.

G6.0	Distance and touch sensors	Mindstorms	Technology, engineering, math	Students program their car to stop when it sees or feels an obstacle.
G6.OE	Engineering challenge	Mindstorms	Technology, engineering	Get Me Out of Here! Design a robot that can find its way out a room when placed in any arbitrary place in the room.

Standards Alignment

A deliverable of this project will be a complete list of curriculum standards the EEC aligns to. Note that the WeDo Teacher's Guide has a national standards alignment section. However, the following list is a partial list of relevant Massachusetts Science Technology/Engineering standards related to robotics. The EEC also aligns to Technology, Mathematics, and English Lanaguage Arts standards.

Physical Sciences Grades PK-2

3. Describe the various ways that objects can move, such as in a straight line, zigzag, back-and-forth, round-and-round, fast, and slow.
4. Demonstrate that the way to change the motion of an object is to apply a force (give it a push or a pull). The greater the force, the greater the change in the motion of the object.
5. Recognize that under some conditions, objects can be balanced.

Physical Sciences Grades 3-5

4. Identify the basic forms of energy (light, sound, heat, electrical, and magnetic). Recognize that energy is the ability to cause motion or create change.
5. Give examples of how energy can be transferred from one form to another.
6. Recognize that electricity in circuits requires a complete loop through which an electrical current can pass, and that electricity can produce light, heat, and sound.

Physical Sciences Grades 6-8

11. Explain and give examples of how the motion of an object can be described by its position, direction of motion, and speed.
12. Graph and interpret distance vs. time graphs for constant speed. Forms of Energy
    13. Differentiate between potential and kinetic energy. Identify situations where kinetic energy is transformed into potential energy and vice versa.

Technology/Engineering PK-2

2.1 Identify tools and simple machines used for a specific purpose, e.g., ramp, wheel, pulley, lever. 2.2 Describe

Technology/Engineering 3-5

1.3 Identify and explain the difference between simple and complex machines, e.g., hand can opener that includes multiple gears, wheel, wedge, gear, and lever.

2.2 Describe different ways in which a problem can be represented, e.g., sketches, diagrams, graphic organizers, and lists.
2.3 Identify relevant design features (e.g., size, shape, weight) for building a prototype of a solution to a given problem.
2.4 Compare natural systems with mechanical systems that are designed to serve similar purposes, e.g., a bird's wings as compared to an airplane's wings.

Grade 6-8

Engineering Design

Central Concept: Engineering design is an iterative process that involves modeling and optimizing to develop technological solutions to problems within given constraints.

2.1 Identify and explain the steps of the engineering design process, i.e., identify the need or problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.
2.2 Demonstrate methods of representing solutions to a design problem, e.g., sketches, orthographic projections, and multiview drawings.

2.3 Describe and explain the purpose of a given prototype.

2.4 Identify appropriate materials, tools, and machines needed to construct a prototype of a given engineering design.

2.5 Explain how such design features as size, shape, weight, function, and cost limitations would affect the construction of a given prototype.

2.6 Identify the five elements of a universal systems model: goal, inputs, processes, outputs, and feedback.

4.2 Explain and give examples of the impacts of interchangeable parts, components of mass-produced products, and the use of automation, e.g., robotics.

6.1 Identify and compare examples of transportation systems and devices that operate on or in each of the following: land, air, water, and space.

6.2 Given a transportation problem, explain a possible solution using the universal systems model.
6.3 Identify and describe three subsystems of a transportation vehicle or device, i.e., structural, propulsion, guidance, suspension, control, and support
6.4 Identify and explain lift, drag, friction, thrust, and gravity in a vehicle or device, e.g., cars, boats, airplanes, rockets.

Evaluating Elementary Engineering Design

In the EEC project, we will capture student work with each open ended engineering challenge. We will look at this work longitudinally by student to see growth over time and to also compare the sixth grade products with the years of engineering experience the student has.

Some of dimensions we look for when evaluating student engineering works are as follows.

- Multiple Solutions? Were multiple solutions considered or did the student only consider a single solution?
- Valid and comprehensive testing? Did the students have a plan to test their solution? Was it thorough? Did they execute the test plan and make any needed fixes and retest?
- Effectiveness at solving problem. Did the solution actually solve the problem? How well did it solve the problem?
- Reflectiveness. Can the student reflect on their solution and process and explain how and why they choose that solution?
- Flexibility. Was the student able to rework solutions that did not work and make changes to their design?

Possible products for capturing these dimensions are:

- Instructions for the product
- Marketing Brochures for the product
- Engineering journals
- Drawings
- Programs
- Photos and videos of products in operation
- Interviews
- Surveys (this will be used to evaluate interest in engineering)
- Testing to evaluate general knowledge of engineering design concepts

Description of Open Ended Engineering Challenges

Kindergarten – Bees and Honey

Lesson Summary

Story context: the bees need their honey but something is blocking the way. Help the bee find its honey. Students must start on the starting tape, and program the BeeBot to find its way to the ending mark (honey.) Students have previously learned to program the BeeBot to follow masking tapes paths on the floor.

Materials

Masking tape, blocks 12 inches long, BeeBots, extra batteries, blank paper, and markers, actual honey jars (optional).

Procedures

TBD

Products

Students draw the final path their BeeBot took to find the honey.

Grade 2 – Amusement Park Ride

Lesson Summary

Invent your own amusement park ride. Students make their own ride. They should use their knowledge or gears, pulleys, and motors to make an exciting and interesting ride. They can add sounds and change directions and speeds to make their ride better.

Materials

Lego WeDo kits and laptops. [Investigate whether extra parts are needed for this challenge.]

Procedures

TBD

Products

Students produce a 1 page ad for their ride.

Grade 4 – Burglar Alarm

Lesson Summary

Design a burglar alarm. Encourage the use of both sensors and the motor. [Should we prescribe a basic house design that has 2 doors?]

Materials

WeDo robot kits and laptops.

Procedures

TBD

Products

Students produce a plan (drawing) for their burgler alarm, which includes a short description of their idea. Students answer the following question: did you stick with your original design idea? If not, what did you change and why?

Grade 6 – Get Me Out of Here!

Lesson Summary

Design a NXT robot that can find its way out a room when placed in any arbitrary place in the room. Students should use sensors (touch or distance) to either look for openings or change course when an obstacle is detected. [Can the robot look for the greatest distance without and obstacle using sensor and motor with the Common Palette?]

Materials

NXT Mindstorms Education Kits and laptops.

Procedures

TBD

Products

Survey that questions the students interest in engineering.

Short test of engineering design principles.

Reflective engineering log that describes what ideas were considered, rejected, modified, the path the robot used, and an English language description of the programming strategy their robot used.

Support Needed

Project Provided

1. More robot equipment for schools
2. Extra Lego parts for the open ended challenges
3. More laptops for use with robots
4. PD for teachers
5. Note that schools with a dedicated teacher is ideal.
6. Consulting – help with child development and engineering research as well as how to evaluate the products.
7. Evaluation
8. Administrative overhead

District Provided

1. Teachers that can implement the EEC. Ideally, districts will have a technology teacher that can work with teachers at each grade level.
2. Teachers will be supported by local administrators in terms of time and resources.
3. Districts may need to provide some laptops if grant funds can not provide all the laptops needed.
4. Teachers will need a computer to take the online part of the course.
5. Teachers will need 3 sub days to take the face to face sessions of the course.

Project Deliverables

1. Professional development – blended learning course(s) to teach teachers the EEC.
2. The purchase and installation of Lego NXT, WeDo, and Terrapin Logo BeeBot robot kits and software.
3. The purchase and/or installation of laptops needed to use the robots.
4. Fully aligned and developed EEC.
5. Platform (TBD) to provide ongoing support and collaboration for participants.
6. An analysis (paper) of the products produced by students.

District and Staff

Districts and staff participating in the EEC project are shown below. [more to be added]

Dr Tony Ryan

tryan@hr-k12.org
Assistant Superintendent
Hampshire Regional Schools
19 Stage Road
Westhampton, MA 01027-9545
Phone: (413) 527-7200

John Heffernan

jheffernan@hr-k12.org
Tech Coordinator
Williamsburg Elementary Schools
1 Petticoat Hill
Williamsburg, MA 01096
http://www.burgy.org/schools/
Phone: (413) 268-8421
FAX: (413) 268-8420

John Schott

schottj@easthampton.k12.ma.us
Technology Director
Easthampton Schools
50 Payson Avenue
Easthampton, MA 01027
Easthampton, MA
Phone: 413-529-1500 x 132

Mary Leyden

mleyden@mac.com
Elementary Curriculum Coordinator
Tech Integration Specialist
Pioneer Valley Regional School District
97 Fort Sumner Road
Northfield, MA 01360
Phone: 413-498-2931
Fax: 413-498-0184

Biographies

EEC will be replicating a successful robotics instructional program that has been underway at Williamsburg Elementary School for the past two years with the WeDo elementary kids and five years with the Mindstorms kits. John Heffernan will provide instruction, coaching and mentoring to teachers. A former software engineer who became a teacher in 1992, John was the first teacher in Amherst to use the Internet and to use modern computers for students and teacher work. At the Hampshire Educational Collaborative in 1999, he led many grants focused on teacher professional development in technology, video conferencing and distance learning. John is currently technology coordinator and technology teacher at the Williamsburg Elementary Schools.

His past experience also includes designing and implementing 3 online courses in PBS Teacherline and Moodle, developing multiple web-based databases for districts, and working for two years at the state level on Virtual Education Space (MASSONE). He joined Williamsburg Schools in 2003, where he introduced robotics, video game programming, and animation creation. In 2008, John received the MassCUE Pathfinder Award for Technology Leadership. Having an experienced teacher deliver the professional development will be critical to the success of the project. John has BSEE and MSEE degrees in Electrical Engineering from Tufts University and a Masters of Education degree from Lesley University.

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