Scientifically Speaking: Best Practices For Science Education With High Ability Children

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Overview

Memorizing facts and conducting canned experiments will help students become technicians, not scientists. Science education in the 21st century must take a fundamentally different approach by integrating all aspects of science, technology, engineering, and math (STEM) in real world problem solving. Project- and problem-based learning aren't new concepts, but can parallel classroom activities with the work of professional scientists who must now integrate multiple aspects of STEM. In particular, emerging materials such as robotics sets can help teachers develop the talents of their future scientists by meeting all of the aspects of STEM with real world challenges in science.

The problem

- A 9-month-old infant, riding in a shopping cart and dropping groceries on the floor to test gravity, has more in common with a professional scientist than most secondary students will experience in school.
- There is a wide chasm between science instruction in most schools and the actual work of scientists.
- If students are fortunate enough to attend a school with resources appropriated to science labs and materials—and many are not so lucky—they are usually made to follow step-by-step instructions.

(based on Coxon, 2015)

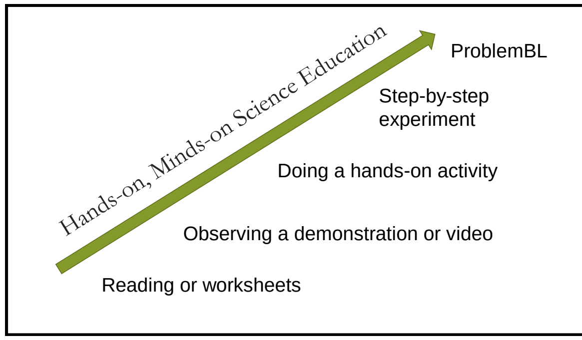
Technicians vs. Scientists

- The best students in this model simply come to a result known by the teacher and long known to science.
- Although it is important to learn to follow instructions, to develop lab skills, and to have a base of scientific knowledge, these should be seen as the floor and not the ceiling.
- These schools are training technicians and not preparing scientists.
- Scientists seek answers to yet unanswered questions and solutions to yet unsolved problems through rigorous methodology, including designing and conducting their own experiments.
- Project- and Problem-based learning are means by which students can prepare to be scientists.

(based on Coxon, 2015)

A key distinction: PBL vs. PBL

- Problem-based learning is a subset of project-based learning
- I define **project-based learning** broadly as a teaching method in which students create some significant product central to their learning goals.
  - Examples: Play or puppet show, a game, a website, a video or book, a research paper or presentation that drives learning
  - Unique products, related to time, and student-centered
- I define **problem-based learning** more narrowly as project-based learning in which students work to solve a real-world problem related to their learning goals.



Problem-based learning

1. State the problem
   1. Ill-structured problem statement
   2. Stakeholder roles
2. Need to know board
   1. What you know
   2. What you need to know
   3. How you are going to find out
3. Research review
4. Investigations
5. Organize findings
6. Communicate findings

   Key opportunity for a project

(based on Center for Gifted Education and Robins, 2008)

PBL Background

- A medical school model
- Used from preschool through graduate school, including in leadership programs
- An ideal method for teaching science

A PBL Example

Your soft drink manufacturing company has been losing money to competitors using real sugar and sugar alternatives instead of corn syrup, which has received a lot of bad press lately.

Corn syrup has been an excellent choice from your perspective because it is cheap, tastes great, dissolves easily, and does not discolor clear soft drinks—some of your most popular sodas.

Your stockholders are upset that you are losing market share as many of your former customers have decided not to consume your current colas, so you must act to keep your job.

Need to Know Board

Know	Need to Know	How to Find Out?	What did you Learn?
Clear is popular	Which sweeteners are available?	Online research	
Cost is important	What do they cost?	Visit store	
Taste is important	How do they taste?	Survey	
Real sugar and alternatives are popular	How easily do they dissolve?	Experimentation	
Easy to dissolve	Are they clear?	Experimentation	

(VanTassel-Baska, 1998)

Some PBL Musts

- Deadlines
- Scientific method
- Regular reporting to the class
- A variety of materials for experimentation
- A final product that matches student abilities and course learning goals
- Rubrics for evaluation, including self-evaluation
- **A change in the role of teachers**

The Overarching Importance of Teachers

- It is important to note that there is no more important aspect in student learning than the teacher (Chetty et al., 2011; Sanders & Horn, 1998).
- In discussions of 21st-century learning, technology is often seen as the heart of the conversation.
- However, there will be little benefit for students from cutting-edge technology (or well-constructed curriculum) without the guidance of an excellent teacher.

(Coxon, 2015)

A paradigm shift for teachers

Traditional

- Classroom is removed from the world
- Teacher and text are sole sources of information
- Work is individualized and simplistic
- Close-ended, single-answer problems
- Students are dominated by the teacher to restrict their movements, discussions, and habits.

Constructivist

- Science classrooms should model real scientific environments
- Multifaceted sources of information
- Teamwork
- Complex, real-world problems for which students develop and conduct experiments to solve facets
- Teachers serve as facilitators and guides.

(Coxon, 2015)

Scientific Habits of Mind

- Curiosity
- Creativity
- Objectivity
- Openness to new ideas
- Skepticism
- Tolerance for ambiguity

(Paul & Elder, 2014)

STEM

- I define **STEM** as the integration of two or more subjects from Science, Technology, Engineering, and Math.
- I believe that while all 4 are important, **engineering** is almost completely absent in K-12 education and **math** is the most neglected in integration; math is often left in isolation and students too rarely see the real-world importance of math to science, engineering, and technology.
- Integrating subjects is simply good teaching.
- STEM is ideal for problem-based learning.
- STEM example: CREST-M math curriculum units where students engineer and program robots to help solve real-world problems in science. (All areas)
  - The first CREST-M unit focuses on CCSS math in measurement for 3rd and 4th grades. Students engineer robots using LEGO WeDo to help solve real-world problems in science such as food distribution.

Robotics

- Robotics education is fundamentally PBL
- Robotics education can integrate all aspects of STEM, though meeting math and science goals requires careful planning
- Robotics competitions are usually good for high ability children and teens

Robotics research

- Robotics use increases scores on spatial assessments (Coxon, 2012a; Verner 2004)
- Robotics use increases scores on creativity assessments (Coxon, 2012b)
- Robotics use increases interest in STEM fields (Coxon, 2012b, Melchoir et al., 2004)
- Robotics use increases motivation for mathematics learning (Coxon, 2015)

FIRST Robotics competitions

- Junior FIRST LEGO League (ages 6-9)
- **FIRST LEGO League (ages 9-14)**
- FIRST Tech Challenge (7th-12th grades)
- FIRST Robotics Competition (high school)

STEAM

- STEAM adds **Art** to the mix in response to the need for creativity in the 21st century.
- STEAM is ideal for project-based learning
- STEAM example: Creating a digital story using iMovie on iPad or equivalent to explain a science concept using storytelling, such as explaining recycling where the character telling the story is a piece of paper. (Science, Technology, and Art)

More ideas for STE(A)M

- Newly discovered animals
- Scratch (scratch.mit.edu) and Alice (alice.org)
- Architecture: Toothpick bridges, craft stick towers, and *GCT* article

Further Reading

Scientifically Speaking in *Teaching for High Potential*

Center for Gifted Education PBL and Clarion units (Kendall-Hunt and Prufrock)

STEM education for high-ability learners: Designing and implementing programming

Serving visual-spatial learners

A teacher's guide to using the NGSS with gifted and advanced learners

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Biography

Steve Coxon, PhD is associate professor and director of programs in gifted education at Maryville University including the gifted education graduate program for teachers, the Maryville Science and Robotics Program, the Maryville Young Scholars Program to identify and serve high ability children from groups traditionally underrepresented in gifted programs, and the Children using Robotics for Engineering, Science, Technology, and Math (CREST-M) curriculum development project. He holds his PhD in gifted education from the College of William and Mary and conducts research on developing STEM talents in pK-8th grade gifted children, especially spatial ability, mathematics, and creativity. Steve has more than 40 publications and 30 juried presentations, is the science education columnist for *Teaching for High Potential*, the book review editor for *Roeper Review*, and is the author of the book *Serving Visual-Spatial Learners*. He serves as an educational consultant, project and program evaluator, and professional developer. In 2014, the Missouri Commissioner of Education appointed Steve to a 4-year term on the Advisory Council on the Education of Gifted and Talented Children. He also volunteers as a judge advisor for FIRST® LEGO® League events in the St. Louis region and as a member of the St. Louis FLL Planning Committee. He has helped to start JFLL and FLL teams at several low-income schools in the St. Louis region. Steve was the 2010 recipient of the Joyce VanTassel-Baska Award for Excellence in Gifted Education.