Mind (not) the gap... Take a risk
Interdisciplinary approaches to the science, technology, engineering & mathematics education agenda

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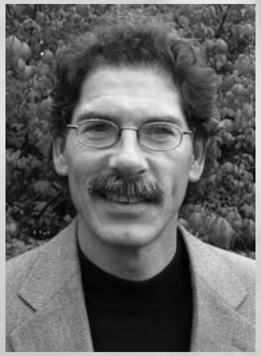

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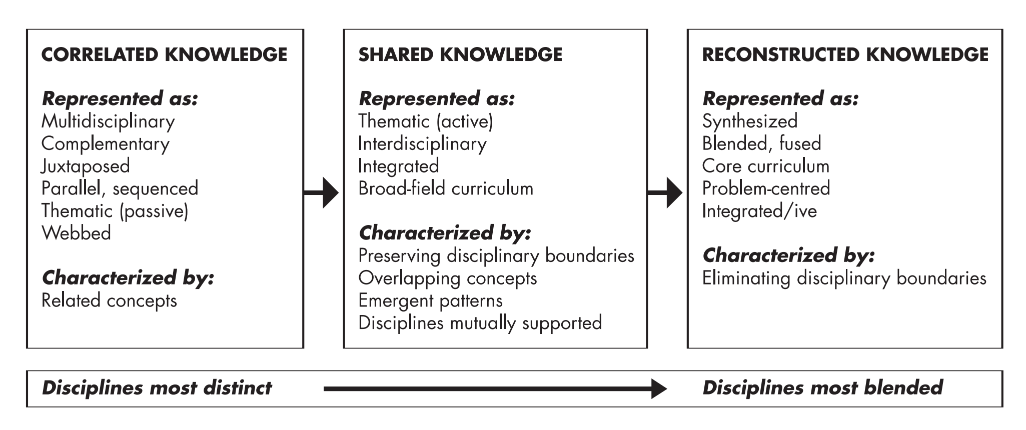
Introduction

There are gaps in the curriculum. These are the gaps between subjects. Students' understanding is diminished by these gaps. Bridging the gaps is not an easy task and not without hazards. But we believe it is worth the effort and the risk! Hence this chapter explores various approaches to establishing interdisciplinary connections between design & technology and other school subjects, particularly science and mathematics. The application of technological, scientific and mathematical principles, tools, and processes is, in effect, what it means to 'engineer' a technological solution to a problem. 'STEM' is now used widely to refer to science, technology, engineering and mathematics. We use the term 'interdisciplinary STEM' throughout this chapter to refer to the inherent connections among these four disciplines. We believe that incorporating more science and mathematics principles, tools and processes into the designing, building and testing of technological solutions has the potential to enhance the already robust pedagogy of design & technology.

Part I: Justifying the interdisciplinary approach

All good teachers draw upon students' prior knowledge, whether this is knowledge previously acquired in the subject being taught, knowledge learned in other subjects in the school curriculum or knowledge gained by students' experience in the world outside school. Design & technology is no exception. Designing, making and evaluating solutions to technological problems draws upon knowledge from a wide range of school subjects: art (aesthetics and visual design), the humanities (socio/cultural/environmental impacts), and English (technical writing, idea presentation). In addition, there is enormous potential for students to apply knowledge, principles and processes learned in mathematics and science classes in designing, constructing and testing the technological solutions they create in design & technology classes.

You can think of interdisciplinary teaching as a continuum that runs from approaches in which the subject areas remain relatively separate from one another, to approaches that completely integrate subject matter and teaching practices. Arthur Applebee, Robert Burroughs, and Gladys Cruz, writing in 2000, described this continuum as ranging from *'correlated'* to *'shared'* to *'reconstructed'* knowledge (shown overleaf).



01 The Interdisciplinary Continuum.

(From Applebee, Burroughs & Cruz, 2000, p.95. Reprinted by permission of the publisher. From Sam Wineburg and Pam Grossman, Editors, "Interdisciplinary Curriculum: Challenges to Implementation", New York: Teachers College Press, © 2000 by Teachers College Press, Columbia University. All rights reserved.)

02 STEM Connections in the human made (technological) world.

Need	How the need is met	Science contribution	Technology contribution	Engineering contribution	Mathematics contribution
Food	Corn				
Clothing	Outdoor coat				
Shelter	House				

Physics Teacher:
'What's the big deal about interdisciplinarity?
I already do technology in my physics class.
For example, teaching "energy transformations" I provide examples of machines like the electric engine motor.
That's technology!'

Technology Teacher:
'What's the big deal about interdisciplinarity?
I already do science in my technology education class.
For example, in my "resistant materials" workshop, students learn about different properties of materials. That's science!'

What do you think?

Contemporary learning theory supports interdisciplinary teaching

Over the past few decades, cognitive scientists have begun to study teaching and learning as it occurs in classrooms like yours. Many of their key findings were summarized and published in 2000, in the book "How People Learn", produced by the National Research Council (US) Committee on Learning Research and Educational Practice. A good many of the conclusions cognitive scientists have drawn from this research may not come as a surprise to you, as they tend to underscore the robustness of established design & technology teaching practices.
For example, some of their key findings include:

- Learning is an active process and learners construct new understandings in the context of what they already know.
- Abstract ideas are learned more effectively if 'situated' in a more familiar and concrete context (situated cognition).
  Thus, for example, Newton's laws of motion are more easily understood when students think about - or better yet, design, build and test - a scaled model roller coaster.
  Along the same lines, students are more likely to understand mathematical relationships among speed, weight and angle of descent in a moving object if addressed in the context of designing and making a model roller coaster, rather than as an abstract 'word or symbol based problem'.
- Learners benefit enormously from discussions they have with one another about their perceptions and ideas.
  For example, describing to one another what they believe is happening in various design/build components of the rollercoaster problem allows students to clarify and evaluate their ideas and 'understandings'. In other words, social interaction is a very important and powerful component of effective teaching and learning.
- Learners achieve their full learning potential by getting just enough outside assistance to enable them to move from what they currently know to a higher level of understanding.

As tackling design & technology problems often reflects so many of these key findings of learning research, Ann Marie Hill and Howard Smith, among others, referred to the type of learning that often occurs in design & technology classes as 'authentic learning'.

Research findings such as these directly support the idea that interdisciplinary teaching that engages groups of students in hands-on designing and making is more likely to promote effective learning of abstract and complex ideas such as those commonly taught in mathematics and science, than do the traditional methods of mathematics and science instruction.

The world outside school is interdisciplinary

Even a cursory analysis of our human-made (technological) world reveals how difficult it is to separate the scientific, mathematical, technological, ethical, aesthetic and socio-cultural components of technological endeavour. We need look no further than the production and consumption/use of outcomes to meet our most fundamental physical needs - food, clothing and shelter - for endless examples of science, technology, engineering and mathematics principles, processes and applications at work.

Can you identify the contributions made by science, technology, engineering and mathematics to meeting the needs identified in the table above?

In our educational institutions, we generally separate the disciplines as a convenience.
In many ways, it is easier to prepare teachers, organize curricula, and teach individually compartmentalized subject areas than to re-think our pedagogical approach with the goal of revealing the interconnected nature of the knowledge, principles and practices within the separate subject areas.
Research on teaching and learning informs us that when we study one subject in isolation from another, it is very difficult to transfer the knowledge from one domain to the other.
In 1983, Ernest Boyer chaired an expert group which conducted a comprehensive study of secondary education in America and then drew this conclusion:
'While we recognize the integrity of the disciplines, we also believe their current state of splendid isolation gives students a narrow and even skewed vision of both knowledge and the realities of the world.'

Educational reform initiatives from around the world support interdisciplinary teaching approaches
Educational reform efforts in the US have called for interdisciplinary STEM approaches. The 'Science, Technology and Society' (STS) movement that began in the 1970s promoted the study of the interconnected nature of science, technology and our society/culture. Many of their ideals were incorporated into the national science, technology education and social studies standards.

'Project 2061' is a massive science education reform project that has been guiding science education reform in the US since the mid-1980s. Project 2061's underlying philosophy, spelled out in their 1993 publication "Benchmarks for Science Literacy" speaks directly to the need for interdisciplinary approaches to math, science and technology education. The report states *'The basic point is that the ideas and practice of science, mathematics and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others…'* (pp. 321-322).

In 1989 the National Council of Teachers of Mathematics promoted the ideal that *'Problem situations can establish a "need to know" and foster the motivation for the development of concepts…In developing the problem situations, teachers should emphasize the application of mathematics to real-world problems'* (p. 75).

The US Standards for Technological Literacy are equally clear about the relationship between science, mathematics and technology. *'Science and technology are like conjoined twins. While they have separate identities they must remain inextricably connected in order to survive… Mathematics and technology have a similar relationship. Mathematics offers a language with which to express relationships in science and technology and provides useful analytical tools for scientists and engineers'* (International Technology Education Association, 2000, p. 44).

Interdisciplinary approaches to STEM education are emerging elsewhere in the world as well. Israel is a strong case in point. As a result of the 1994 report of the Tomorrow '98 Project written by Haim Harari, in 1994, the science and technology education curricula in Israeli junior high schools (grades 7-9) were combined into one mandatory subject - 'Science & Technology'. In addition, a new 'Science & Technology' national curriculum was developed, with collaboration between science and technology education as a central ideal:
'…Collaboration between science and technology is essential because of the growing linkage between scientific subjects and relevant technologies and also because of the unclear borders between them'
(Israeli National Curriculum for Science and Technology 1996, p. 5).

It was believed this approach *'will expose the student to science and technology aspects and will introduce the social connections while emphasizing the combination between them'*
(Israeli National Curriculum for Science and Technology 1996, p. 6).


03

03 James Dyson, the inventor of the dual-cyclone vacuum cleaner.

In 2002, the Israeli Ministry of Education and Ort Israel began developing and implementing new high school level science and technology/pre-engineering disciplines and subjects that reflect relationships between science and technology in new multi-disciplinary ways. As Professor Kenny Price, Head of the 'Amos De-Shalit Science Teaching Center' at the Hebrew University described it:
'The concept behind this curriculum differs substantially from the traditional curricula teaching methods of science and technology, especially regarding contents interrelationships and particularly the teaching method. Technology is presented as an integral part of the science curriculum; learning about various types of technologies is combined with science education, so that students develop a viewpoint of science and technology as an unified whole'.

The most recent rewrite of the programme of study for design & technology in England includes the statement: *'make links between design & technology and other subjects and areas of the curriculum'* (Qualifications and Curriculum Authority 2007, p. 57)

In addition, specialist Engineering Colleges, catering for students aged 11 to 19 years, have the following as part of their vision statement:

'Through a focus on enhancing understanding of the relationship between design & technology, mathematics and science, underpinning a broad curriculum, engineering colleges will raise standards of achievement for all students across the ability and subject range, leading to whole school improvement by providing increased diversity through opportunities for students to follow a wide range of vocational pathways'.
(Barlex 2005, p. 12)

James Dyson, the inventor of the dual-cyclone vacuum cleaner and advocate for design & technology education, has recently unveiled plans for a new college aimed at encouraging young people to become engineers.
The Dyson School of Design Innovation - due to open in 2009 in Bath - will teach 2,500 14 to 18 year olds design, engineering and enterprise.

What are your views?
Despite educational reform efforts that encourage interdisciplinary efforts among STEM and other school subject areas, successful implementation depends largely on the ability of the teachers involved to make it happen. The reasons noted above provide a rationale for doing so… but examining this issue from your perspective is a very important first step. You need to decide where you stand.

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Given the support for an interdisciplinary approach it seems obvious that teachers should pursue this path.
But is it really that simple?
Consider what Franzie Loepp and John Williams have to say:
'Educational researchers have found that an integrated curriculum can result in a greater intellectual curiosity, improved attitude towards schooling, enhanced problem-solving skills and higher achievement in college'
(Austin, Hirstein and Walen 1997; Kain, 1993)
(Quoted in Loepp, 1999).

'While the relationships between science and technology are undeniably significant, the differences between the two areas are just as important, particularly in terms of the goals of the developing area of technology education… the differences in methods, aims, use of knowledge and types of knowledge are fundamentally significant enough to teach them separately…'
(Williams, 2002).

Who do you think is right?
State your reasons for taking sides. Develop some arguments to persuade those who think differently from you.

When James Pitt and David Barlex investigated the views of science and design & technology teachers in England in 2000 they found that the teachers had shared and consistent views of the subjects they taught but there was considerable ignorance of each other's subjects. A case study of science and design & technology teachers in a large secondary school in Sheffield carried out by David Barlex, Colin Chapman and Tim Lewis in 2003 revealed that this ignorance could lead to antagonism that was counterproductive in forming a useful relationship between the subjects. So it is important to develop an understanding of the curriculum areas you don't teach as well as those you do.

Do you know what your colleagues think about the subject they teach?
Here's a chance to find out.
Get together with other STEM teachers and complete the table below collectively, discussing ideas as you go.

Delete the 'sample' information in the 'Science' column before you begin… it is included here only to clarify the intent of this activity.

04 Interdisciplinary Connections among STEM Disciplines.

Criteria	Science	Technology	Mathematics	Engineering
Primary domain of concern?	Natural world			
Provides answers to the question…?	What is?			
Activity guided by…?	Inquiry, observation, theories, principles			
Primary endeavor?	Explain natural world			
Success determined by…?	Theories validated by other scientists			
Disciplines organized by…?	Laws and principles			
General approach	Research			
Resulting outcomes?	New explanations and theories			
Formal education occurs at what levels?	Grades K-16			
Signature pedagogy	Inquiry			
Connections with which (if any) of the STEM disciplines?	Technology, math & engineering			

05 Students in years 7 and 8 use a slope to investigate the effects of friction and velocity while working on a car safety problem.

06 - 08 Developing inflatable safetywear for cyclists. Bicycle airbag ‘test drive’.

Designing and making as a focus for STEM

Design problems commonly used in technology education generally require students, working individually or in teams, to:

1. identify and clarify problems;
2. conduct research which might involve investigations;
3. generate one or more design proposals;
4. develop these so that they can be scrutinised for predicted performance and social/environmental impact;
5. construct a prototype of the most promising design, experimenting with subcomponent designs as necessary;
6. test/evaluate the constructed solution.

During this process the students should document all design, construction and testing procedures; and be involved in communication with their peers and teacher. It is tempting to see 1 to 6 as a linear process but in reality we know that the stages not only inform one another but are to be revisited according to the demands of the emerging design. Hence students will use their mathematics and science as and when they need to, depending on the particular issue they are trying to resolve.

The various phases of the designing call on the use of mathematics, science and designerly speculation. Mathematical prediction and analysis will be useful in 1, 4 and 6. Scientific enquiry will be useful in 1, 2 and 5. Designerly speculation will be required in 3, 4 and 5. This is sometimes referred to as ‘trial and error’ but this term devalues the importance of this activity. Asking a series of ‘what if’ questions about changes to a subcomponent and using these to move to an improved design requires rigorous thinking that can be informed by mathematics and science. Thomas Edison, for example, said he found 5,000 ways to make a light bulb that wouldn’t work! Engineers routinely employ all three strategies: mathematics, science and ‘designerly speculation’ methods, in the design of technological solutions.

One of the unique aspects of design activities is their ability to support developmentally (age) appropriate math, science and trial and error problem-solving. Even simple design problems generally have the potential to support the application of scientific inquiry and/or mathematical analysis at any level of sophistication, thereby offering appropriate challenges for students who come to the activity with robust science and math knowledge. Likewise, trial and error methods range in sophistication, depending upon the ages of the problem-solvers and the prior knowledge they bring to the problem. Teachers may gear the sophistication of the science, mathematics, and technological applications to align with students’ current developmental capabilities. In practice, students may ‘self-select’ the level of sophistication at which they work. If students choose to go beyond the teacher’s comfort zone with their mathematics, science or technological inquiry, the teacher should take heart in the fact that design activities allow students to reach their maximum learning potential in each of the STEM areas. This may be the time and place for design & technology teachers to involve fellow science and/or mathematics teachers in the activity.

Here are some examples of some technically focused designing and making activities that might be called engineering.

The “**West Point Bridge Designer**” software, used in many schools in the US and England (http://bridgecontest.usma.edu/index.htm) allows students to analyze bridge truss designs instantly after changing one of the components in the design. The software quickly computes a cost associated with a change in the truss design. In a problem like this, algebra might be used to determine the strength to weight (supported) ratio of a particular truss design. Mathematical analyses like these inform the design process, enabling students to make better design choices than they might, had they not used any analytical procedures. Similarly, a scientific investigation of the strength of materials used for bridge design could assist students in designing and re-designing bridge components. The prototype construction phase of the design process generally allows opportunities for designerly speculation, a way of problem-solving, an important and most useful aspect of designing.

In Israel students in years 7 to 9 study a science & technology curriculum. Although it has been established as one subject (science & technology), it is recommended that there should be different teachers who specialise in different topics of the curriculum and collaborate in their teaching through project-based learning. In the example shown above left, students are working on a car crash safety design problem. Naturally they conduct experiments using physical science concepts such as force, friction, velocity, acceleration and momentum. In the example above students were developing the design of an inflatable safety device for cyclists. This was based on the idea that inflation would occur just before the bicycle tipped over but would remain deflated during normal use including cornering at speed. The need to sense and measure velocity and angle to some degree of accuracy was necessary. Clearly no shortage of mathematics or science here and this demanding project won first prize in a national competition.

A particular tricky question is just what makes the engineering component different from other forms of designing and making. Is it simply the use of science and mathematics? Or in tackling engineering style designing and making do students need particular knowledge, understanding and skills not required for other areas of designing and making?

Help these poor characters below figure out the relationships among science, technology, mathematics and engineering education!

Make your own illustration to describe these in general terms.

Describe an engineering activity and use your illustration to show the interactions that take place.

09 What are the relationships between science, technology, mathematics and engineering education?

Here are some designing and making activities. What potential does each have for using mathematics and science?

- A high-energy food bar for use on an expedition in a cold climate.
- A child's outdoor coat that is easy for the child to put on and take off.
- An alarm clock that comes on just as the sun rises.
- A pop-up greeting card with an audio message.
- Outdoor seating that can be folded up for easy storage.

The Royal Academy of Engineering (2000) defines engineering as *'the knowledge required, and the process applied, to conceive, design, make, build, operate, sustain, recycle or retire, something of significant technical content for a specified purpose; a concept, a model, a product, a device, a process, a system, a technology'* (p. 5).

Given this definition do you think any of the activities listed could be called engineering? Explain your reasons.

Pick a design activity with which you are familiar and identify and describe opportunities for students to engage in:

1. qualitative analysis (e.g., involving careful observation rather than mathematics);
2. quantitative analysis using age-appropriate math;
3. scientific investigation and the use of scientific concepts; and
4. designerly speculation.

Because technological design problems offer such a rich environment for revealing the connections among the STEM subjects, technology educators may play a key leadership role in interdisciplinary STEM teaching, primarily by taking advantage of the math and science opportunities inherent in technological problem-solving.

An interdisciplinary STEM approach

10 The "Interaction" report.
(David Barlex and James Pitt; © Engineering Council UK.)

is fundamentally about seizing rather than avoiding the opportunities to incorporate math and science into the technological design problems used in technology education.

Part II: Interdisciplinary STEM approaches

> ?
> If you wanted to connect the STEM disciplines, what do you think would be the best way to go about it? That is, what do you think the ideal working relationship among the science and technology and mathematics teachers would look like?

As noted earlier, interdisciplinary teaching approaches fall along a continuum, from those that involve relatively little collaboration between/among the teachers involved, to the full merger of content of two or more disciplines to create an entirely new course. Recently David Barlex and James Pitt used the experience of secondary schools in England to write the Interaction Report about the relationship between science and design & technology in the curriculum. They describe three possible interdisciplinary approaches that mirror those identified by Arthur Appleby and his colleagues: coordination, collaboration, and integration.

The coordinated curriculum approach
The coordinated curriculum approach… *'involves teachers in each subject being au fait with the work carried out in the other and planning their curricula so that the timing of topics within each subject is sensitive to each other's needs'*. It is the least disruptive of these three approaches. In theory, each teacher continues to teach what and how they've taught in the past, simply re-scheduling when they teach these concepts/activities, so students encounter similar and complementary ideas concurrently in each of the participating subject areas. For example, a course in physical science might address magnetism and electromagnetism at the same time students in technology education design, construct and evaluate magnetic levitation vehicles powered by a small electrical motor. The math teacher might instruct students on algebraic relationships - in parallel with the idea of electromagnetic strength relative to the number of windings on a coil. Each teacher might reference this unit in the other two classes, highlighting the cross-curricular connections, without substantively altering their approach to the unit they're teaching. Curriculum frameworks such as the National Curriculum in the UK are a good first step in facilitating coordinated teaching, as they draw attention to what is being taught in each of the subject areas, including design & technology, science and math.

This 'framework' begins to make it possible to see the content connections among the subjects, which in turn allows teachers to coordinate their teaching.

The collaborative curriculum approach
Given typical scheduling constraints in education, it is problematic to completely coordinate teaching schedules in different subject areas. For that reason, it may be more plausible to work toward interdisciplinary collaboration rather than coordination. In the 'collaborative' model, STEM and other teachers might work together to identify an educational activity that has potential for cross-curricular connections. Technological design problems are ideal for this purpose, as they present ample opportunities to apply technological design principles, scientific inquiry and mathematical analysis.

> ?
> **Objectionable noise**
> Consider working on this reflective activity collaboratively with a science and/or math teacher in your school.
>
> Part I
> 1. Review the article "The Noise Around Us" at this URL http://www.iteaconnect.org/Conference/PATT/PATT13/PATT13.pdf
> 2. Consider the noise and noise-related problems in your immediate environment (home, neighborhood, school).
> 3. What noises are there that are bothersome or potentially harmful to your hearing?
> 4. Is there anyone in your family with a hearing problem?
> 5. What are the social implications of noise and/or hearing problems?
>
> Part II
> Science concepts associated with sound include vibration, frequency, amplitude, wavelength and loudness. Math students learn to plot graphs of data to help us visualize patterns and relationships.
> 1. How might you develop this activity in a way that

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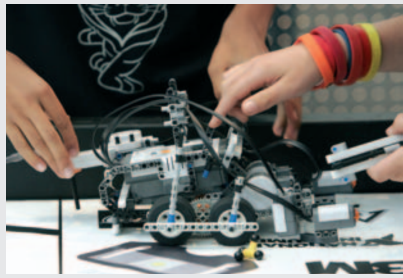
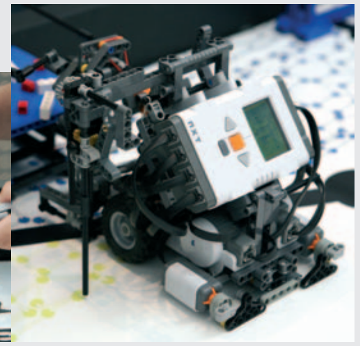
11 & 12 FIRST Robotics. (Photographs by Adriana M. Groisman, courtesy of FIRST.)





13 - 15 FIRST Lego League. (Photographs by Adriana M. Groisman, courtesy of FIRST.)

would engage students in the use of principles, concepts and processes from science and mathematics?

2. Develop a 'design brief' that challenges students to design solutions to objectionable 'noise problems' in their community (home/school/neighbourhood).
3. Identify ways of structuring this activity in your particular school setting that would facilitate collaboration among technology education, science and math faculty.

The integrated curriculum approach
Barlex and Pitt describe the integrated curriculum approach as the merging together of multiple subjects - in this case, science, technology education, engineering and mathematics - into a single 'integrated' course. They consider this an inappropriate arrangement, because *'science and technology education are so significantly different from one another that to subsume them under a "science & technology" label is both illogical and highly dangerous to the education of pupils'*.

?

How do you feel about the 'integrated curriculum' approach, in which science, design & technology and math would be taught as one subject? Can you envision such a course? If so, what would it look like? Would you be comfortable teaching such a course? If so, why, if not why not? What do you think it would take to enable you to feel comfortable teaching such a course? If such a course were developed and taught effectively - perhaps by a team comprised of all three (design & technology, science and math) teachers, do you think students would benefit more or less from this approach than from the coordinated or collaborative models described above?

Extracurricular interdisciplinary STEM approaches
Educational infrastructures create significant challenges to those trying to make interdisciplinary connections during the regular school day. The remarkable global success of programs such as "Odyssey of the Mind" (founded by a technology teacher educator) and the "FIRST Robotics" and "FIRST Lego League" competitions (founded by an engineer) are testimony to the vast potential of interdisciplinary STEM activities. A great part of their success results from the fact that they are extracurricular activities. By moving these activities out of the conventional classroom/curriculum the following advantages, among others, may be realized:

- students and teachers may concentrate on the application of math, science and technological principles to 'authentic' problems, rather than focusing on a specific set of ideas to be formally assessed with 'high stakes tests';
- competitions often challenge/motivate students in a way conventional coursework rarely can;
- collaboration/social interaction - known to facilitate more effective learning - is more likely to occur, since students are not competing against one another, as is often the case in conventional classrooms;
- scheduling problems are a non-issue, since students are free to use math, science and technological principles and methods at any point in the process.

This is not to say extracurricular interdisciplinary STEM activities aren't without a downside. Drawbacks to the extracurricular approaches include the following:

- there are often significant expenses involved (e.g., "FIRST Robotics" is a very expensive program to operate);
- most extracurricular competitions are relatively short in duration (e.g., "FIRST Lego League" engages students actively for only about 6 weeks during each school year;
- they often engage only a small percentage of students (for example, the FIRST competitions typically involve fewer than 5% of students in participating schools; and
- most schools and students choose not to participate in extracurricular design activities.

?

How might some of the benefits associated with extracurricular interdisciplinary STEM activities be incorporated into the regular school day?

Part III: Pathways to interdisciplinary STEM connections

Interdisciplinary connections between technology education and other disciplines aren't likely to occur unless someone takes the initiative. If the idea of 'making connections' between design & technology and other school subjects interests you, don't wait for the others to come to you (you'll likely be waiting for a *long* time!). Rather, begin to promote this idea to fellow teachers and administrators in your school. Start small. See if you can begin a collaboration between science and design & technology, math and design & technology or math and science. If you can get that working, try to bring in the third subject area as well. Before you venture out with this idea, know that interdisciplinary teaching in state schools *is an attainable goal!* We know this, because many middle schools throughout the US - serving youngsters approximately 11-13 years of age - have managed to change their philosophy, infrastructure, curriculum and teaching practices to develop and implement highly successful interdisciplinary teaching. The National Middle School Association has publicly espoused interdisciplinary teaching since the 1980s. The 2002 version of their "Position Statement on Curriculum Integration" stipulates *'We must encourage middle level educators to push themselves beyond the conventional, separate subject format and to expand their use of integrated curriculum formats, ranging from intra-team planning of interdisciplinary units at a basic level to more advanced implementation of full-scale, integrative programs in democratic classrooms'*. Their position statement includes the following bold assertions:

1. *'The greater the degree of integration, the greater the benefits;'* and
2. *'Students in integrated curricula generally do as well or better on standardized tests than do those in conventional curricula'*.

Bringing administrators and collaborators on board

Successful transition to interdisciplinary teaching requires commitment from school administrators, participating teachers and the community. Administrators must be willing to provide a supportive environment, which includes planning time for teachers and flexibility with respect to class facilities scheduling. Design & technology educators should look for willing collaborators in the STEM disciplines, but may also reach out to the art, social studies and English teachers. Again, it's good to start small, and expand the partnership, expanding with cautious optimism as you gain confidence. 'Purposeful socializing' may help you get started. The cultures of the STEM disciplines are very different from one another. Differences between strangers are often perceived as barriers, but those same differences might be seen as learning opportunities among friends. So conversations are a very important first step.

?

Getting Started - Purposeful Socializing

Interdisciplinary teaching isn't going to occur as long as the participating educators (e.g., STEM faculty) are strangers to one another. Make a plan to have lunch with one or more prospective collaborators, with the idea that you'll chat informally about your teaching. If collaborative opportunities present themselves, consider experimenting with those opportunities. Start small and build from there.

Also, consider inviting a math and/or science teacher to observe your students as they present their designs to classmates…an ideal way for them to begin to see the possibilities for interdisciplinary connections.

As you talk with other STEM educators, it might be helpful to point out that one design problem can challenge all levels of students. For example, one student might approach a design problem requiring volume estimation by using water displacement to arrive at an estimate; another might resort to a 3D CAD program for this, and a third might turn to calculus. Alternative approaches like these are consistent with contemporary ideas about mathematics teaching.

In conclusion

Karen Zuga observed in 1996 in the book "Science-technology-society as reform in Science" *'Communities of technology and science educators have been passing as two ships pass silently in the night without speaking to each other about their relationships'* (p. 227).

This is a sad but true reflection on the state of interdisciplinarity. Despite the patently obvious relationships among the STEM disciplines beyond the walls of the school, STEM educators have become estranged from one another. The differing interests and dispositions of these individuals led them to four distinctly different directions, yetthere are undoubtedly grounds for some forms of working together. Political and economic realities make it easier to work in isolation than in collaboration, yet we are forced to ask: Would STEM education be significantly better if approached collaboratively rather than competitively? Would the whole be greater than the sum of its parts? Would students and teachers benefit in the long run? Would the relatively unproven claims of STEM education reformers be substantiated if the experiment were carried out to its logical conclusion?

Vera John Steiner has written at length about the issues facing those who wish to work in an interdisciplinary way in her book "Creative Collaboration".

Vera argues that it will require a wide range of partnerships over a prolonged period of committed activity. These partnerships thrive on dialogue, risk-taking and a shared vision. These partnerships will need a high level of support. The work of these partnerships will be highly demanding but essential. Collaboration in creating an interdisciplinary STEM curriculum will be an emotional as well as an intellectual process. Successful collaboration always involves trust and this has to be earned by those working together. Without trust it is not possible to reveal and overcome the insecurities and uncertainties that underpin all creative endeavours. The decrease in personal autonomy that accompanies close collaboration can best be achieved in an environment of trust where people come to value each other's contribution that expands their own resources. To achieve this, those working in collaborative STEM endeavours will need to take the bold step of becoming dependent on one another. This dependence is not a sign of weakness, but of strength. It is a dependence that will allow individuals to make substantial professional growth through partnership. Above all it is a dignified interdependence through which those working together have mutual respect and can forge achievements far beyond their individual, isolated capacities.

So we urge you **MIND (NOT) THE GAP… TAKE THE RISK!**

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