Thinking Like Telford

Thomas Telford Engineering Challenge

A Pilot Project for Senior Technological Design

PEO Education Conference

May 14, 2016

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- Chair, PEO Education Committee (EDU), 2010 to 2012
- Member, OSSTF District 12 Professional Development Committee, 2009-2012
- Chair, PEO Engineering Education Conferences
    - 2008 – "What Students Want to Learn"
    - 2009 – "Outreach Through Partnerships"
- ***Math in the Woodshop*** Aspiring Engineers project -- took 4 grade 9 students to 2014 PEO EDU Conference
- Speaker at Ontario Association for Mathematics Education 2016 Conference
    - ***Algebra is a Balance: Extensions to the Law of the Lever***

The theme of the 3 Scarborough panels of the Scottish Diaspora Tapestry is the relationship between Scottish settlers and the Ontario forest.

Thomas Telford Engineering Challenge and the Scottish Diaspora Tapestry

- The Scarborough exhibition of the 304-panel / 500 foot Tapestry will be unique.
- Senior Tech Design student teams are invited to design a 36-foot long model of the central unsupported span of the Menai Suspension Bridge by which to hang the Tapestry at the exhibition.
- The Menai bridge, having a central unsupported span of about 175 m, was designed by Thomas Telford (ca 1820).
- Telford apprenticed as a stone mason alongside Andrew and Archibald Thomson, two of Scarborough's earliest European settlers. Their father was the mason.

Thomas Telford's Menai Bridge

http://www.engineeringhalloffame.org/profile-telford.html
Arguably the world's first modern suspension bridge

But There is a Serious Catch…

- ***"No holes may be drilled in walls, floor, ceiling"***

- How is it possible to build a model suspension bridge without anchoring the towers to a wall or the floor?
- 2016 is ***Scotland's Year of Innovation, Architecture and Design***.
- The design work two centuries ago behind this new kind of bridge certainly involved innovation and both critical and creative thinking.
- The *Thomas Telford Engineering Challenge* will get students to practise the kinds of thinking that Telford probably used in order to "*come up with this new kind*" of longer-span bridge.

Requirements / Constraints Include:

- The available space in the auditorium of St. Andrew's Presbyterian Church, Scarborough, is 44 feet long by 40 feet wide
- No holes may be drilled in walls, floor, ceilings
- Tables are available upon which supplementary Tapestry text will be displayed and above which the Tapestry must be hung:
  - The tables are each 48 inches long and 30 inches wide and 30.5 inches high
- The bridge must span more than 32 feet, but not greater than 36 feet (ie between the towers)
- The bridge must accommodate the prominent display of at least 240 panels, each of size 540 mm by 540 mm.
- The bridge must be constructed of wood (with the exception of the cables and fasteners)

- All submitted design materials must be electronic
- In total, the Scottish Diaspora Tapestry is over 500 feet long, being comprised of 304 fabric panels of 540 mm by 540 mm each.
- The total mass of all panels is 100 kg.

Evaluation of Submitted Designs

- Analysis of Suspension Bridges such as the Menai Bridge
- Technical Reporting (Design Process documents)
- Design (including strength, stability, efficient use of materials and other fundamental concepts of technology in this context) (clearly stating assumptions)
- Build / Construct a 1:10 scale model of the design
- Test / Monitor Stresses / Evaluate / Conclude
- Knowledge and Understanding of relevant fundamental concepts and processes (Reports from the Moodle quizzes at http://thinkproblemsolving.org)

Achievement Categories… During the Challenge… the Student Will…

Come to Know and Understand (Concepts & Processes)

- 3-Dimensional Parametric Computer Aided Design
- Safety in a shop using wood-working tools
- Principles of working on an engineering design team
- Other concepts, procedures and work habits important in engineering problem-solving
- The thinking processes and strategies used by innovators like Thomas Telford, civil engineer
- The nature of forests – and trees and lumber – as a valuable and (if managed properly) sustainable resource

Reason-Out for Themselves (Thinking / Inquiry)

- **Plan**
  - Identify the problem, select strategies and resources
  - Assign tasks and due dates to team members and use sound principles of design team project management
  - Pose questions that need investigation / answers
- **Solve Problems**
  - Using Critical & Creative Thinking, Tools of Math and Concepts of Science
  - Use the design process to find and thoroughly document a solution – how to creatively exhibit almost 300 tapestry panels, each of which is 540 mm square
  - Practice the kinds of thinking that the innovator Thomas Telford probably used in his development of the modern suspension bridge
- **Process Information**

Communicate to / with Others (Communication)

- Produce design process documents:
  - Design Brief
  - Research Report and Requirements
  - Specifications
  - Task List
  - Design Drawings, Parts List
  - Fabrication Plan
  - User / Assembly / Installation Guide, Warning Labels, Promotional materials
  - Test Report
- Collaborate with other team members verbally, visually and in writing (four to six students per team)

Do and Practice (Application of Skills)

- Use a parametrically-driven 3D Computer Aided Design package to design a 36 foot long model of the unsupported central span of the Menai Suspension Bridge
- Use wood-working tools to build a four foot long model suspension bridge – a 1:10 scale model of their design
- Instrument the four foot bridge using strain gauges and a relevant hardware / software platform
- Trigonometry, algebra, free-body diagrams, law of the lever, cancelling units of measure – and other tools of math and concepts of science
- Improve sound work habits
- Improve essential skills

A Teacher's Reflection

- The balance between learning about new concepts and doing design work was reasonably fair and do-able for students who aspire to engineering.
- I would not reduce the "Fundamental Knowledge" component (including some key principles of suspension bridges, structural analysis, strength of materials and extensions to the "law of the lever").
- I believe I hit the fundamental knowledge, the math and the physics at a very fair grade-12-university-bound level.
- Students now have a solid appreciation for the notion of "uncertainty" in the world of design (hence, the importance of safety factors).

Teacher's Reflection (2)

- The listed judging criteria (Evaluation) were quite reasonable.
- Three versions of a sample design portfolio were distributed at various milestones during the project.
- The samples were deliberately incomplete and imperfect – otherwise students can just follow a teacher's template as though it is just another fill-in-the-blanks form.
- I would not give students a prescribed format for their technical report. Technical communication is a skill which students must learn, practice and improve by doing their own critical thinking and peer assessment.

Teacher's Reflection (3)

- Cooperation from judges was exceptional – many thanks to the judges for their time.
- In their reviews of the teams' submissions, the judges were very fair and pointed out many additional items that could (perhaps should) have been addressed in the teams' technical reports.
- The simple email format for sending the technical reports and receiving the judges' findings worked very well.

Teacher’s Reflection (4)

If the Telford Engineering Challenge were to go province-wide, my suggestions for improvement are:

1. Set very firm deadlines for key milestones in the design process (with clear buy-in from all teams). Impose “Late Penalties” if milestones are missed -- in terms of marks (however this is frowned upon in education circles).
2. Force the design team management roles more rigorously. A detailed design team roles test would be a good idea in the early going – knowledge, thinking and communication to be marked.
3. *Next…*

Teacher's Reflection (5)

3. While all but one student in this class had been given solid exposure to 3D CAD in grade 11 tech design, a bit more detailed review of parametric design principles might have helped some students in this project. One dedicated test using 3D CAD should have been run right after the CAD review and practice – to be marked as Application.
4. In the judging criteria, include several of the additional "look-fors" that were pointed out by the judges. I would stop short of making the list exhaustive because students should be doing their own critical thinking around ***"How can we make our technical report better than all of the others***". Perhaps the judging criteria should be clear that the technical report should be akin to a formal response to a "Request for Proposal" or even a construction contract.

Teacher's Reflection (6)

5. At least three PEO chapters should be committed to:
   - -Promoting the Challenge to their district schools
   - -Registering at least 3 teams per district
   - -Arranging for at least one judge
   - -Mentoring (an optional activity)

Just to be clear: This Challenge is intended for Grade 11 or 12 Technological Design students.

Anonymous Student Survey

Names not requested. No names given.

On a scale of 1 to 10 with 10 being *awesome*, how would you rate the "***Thinking Like Telford Menai Suspension Bridge Model***" Project?

#	Learning Experience	Average Rating / 10
1	Telford was a good learning experience in terms of Problem-Solving	8.1
2	Telford was a good learning experience in terms of improving individual Essential Skills and Work Habits	8.1
3	Telford was a good learning experience in terms of team collaboration	8.6
4	Telford was a good learning experience in terms of development and application of shop skills	8.3
5	Telford has good potential as a province-wide engineering challenge	8.9

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Many thanks for your attention

Questions and Comments?