Improving and Assessing Research, Design and Reporting Skills of STEM Students

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The 2014 University of Calgary Conference on Postsecondary Learning and Teaching
May 13-14, 2014

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Interactive presentation goals ...

1. Identify a range of needs and contexts for teaching & learning research, design and reporting skills.

2. Present our approach to improving students’ abilities to ...
   - Tackle open-ended design projects;
   - Synthesize results into efficient written reports.

   → What was done (“methods”)
   → Results of what was done.

3. Discuss applicability, costs and benefits in settings suggested by everyone here ...

Our context ...

Setting: Improving & assessing research / design / reporting skills

• 4th year course for geotechnical engineering students.
• First exposure to “design practices”.

The challenge(s):
• “The first design project is always a disaster.”
• “They have no clue how to begin an open-ended design task.”
• “many reports are hopeless – they miss obvious components.”
• “Some TAs are great! Others ... not so experienced ...”
• “Students can not handle geological uncertainty with maturity”

“Engineering design is hard to learn and harder still to teach” Clive et al, 2005.

Example:
One-sheet with an open-ended design project

“You have been contracted to perform a kinematic analysis and to design a rock bolt pattern to achieve a Factor of Safety of 1.5 against wedge failure in the chamber roof. Make sure to list all assumptions. The rock bolts available from your supplier, and their properties, are provided.”
What are YOUR contexts for developing research, design and/or communicating skills.

Settings ...
• Science? Departments?
• Arts? Departments?
• Applied science or engineering?
• Others?

Articulating Challenge(s)?
• “...”

My plan here ...
• Run through steps in our development sequence
• Summarize some indicators of “success”
• Revisit YOUR settings
  – discuss pros, cons, costs, challenges, opportunities ...

• Email details (slides) plus a reference list to those on the participation list.

Challenge that sparked this project
Feedback compiled by TA: similar for all four design projects

IN OTHER WORDS ... “Wisdom can’t be told ...”.

“Theoretical” underpinnings:
• Highly “expert” tasks: Experts have...
  – Deep foundation of (fluency in) factual and procedural knowledge;
  – Well organized conceptual framework for that knowledge;
  – Discipline-specific metacognitive abilities.

• Novices progress towards expertise by “deliberate practice”.

• “Deliberate” means targeted at improving specific abilities.

• Expert instructors can make opportunities for students to practice deliberately, and generate feedback at critical points.
Aim for consistency with best practices:
EG: Table 1 in Litzinger et al, 2011, a metastudy on education and development of engineering expertise.

- Affective
  - Raise interest, challenge, motivate, relate to needs/interests
- Cognitive
  - Prior knowledge, deep engagement, integrate skills / knowledge,
  - Scaffolding, timely feedback,
  - Formative assessment and summative evaluation
- Metacognitive
  - Self regulation, awareness of progress and needs, reflective
  - Feedback about learning progress and skills
  - Engage “collective reasoning” (teams / groups); i.e. peer feedback

Thoughts / questions on underpinnings?

Resources and “costs”

- 1 experienced and confident graduate TA
  - Working in industry & pursuing an M.Sc.
  - TA’d in this course once before
  - Paid 1 full TA-ship during summer to help develop strategies and tools
  - Piloted the activities and assessment rubrics
  - Shared this role a third time with a new TA.
    - ~100 hrs during a 4-mth summer
    - Normal TA duties during the teaching term.

- 1 Teaching and learning support
  - “Science Teaching and Learning Fellow” (me ☺)
    - ~ 40hrs over 4-mth summer
    - ~ 20hrs over 4-mth teaching term

- 1 lead instructor (Prof. E. Eberhardt)
  - Occasional meetings for updates and to “approve” actions.
  - Our changes must fit with this course that HE teaches.

Sequence of steps ...

1. Analysis of expertise; establishes a framework for work
2. Corresponding tools = process-oriented rubrics
3. Instructional scaffolding of authentic tasks
4. Mentoring of graduate teaching assistants (TAs)
Step 1: Analyze expertise (develop framework)

1) Framework for approaching open-ended design problems:
   - Initial challenges discussed by interviewing TA:
     - Anecdotes about grading challenges.
     - Narrative of the Design Problem (DP1)
   - Convert the narrative into an outline
     - The “generic process guidelines” outline.
     - BUT, the narrative is “just telling” ... and ... “Wisdom can’t be told”, Gragg 1940 & Bransford et al. 1986. (more on this later)
   - Modify the generic process for each specific problem.

Step 2: Develop tools and strategies to foster design & reporting expertise

Compare “expertise” for your contexts with a neighbor
How would you deconstruct expert tasks?

Analyze expertise ...

2) Framework for synthesizing and communicating results
   - TA collected comments provided on graded work
     - See earlier ...
   - Based on the “process-outline” for specific problems, define criteria for each process component.
   - This became the rubric.
   - Are rubrics an effective alternative for steering and assessing high-level skills – like engineering design?
     Eg. Woodhall 2008.

   • A feedback and grading rubric
     - Similar to Hafner and Hafner, 2003 (for “oral presentation”; biology)
   • Have students deliberately consider what might be involved.
     - A facilitated workshop run by the TA.
   • Incorporate experts’ procedures into the assignment.
   • Assess work USING this procedure so feedback is targeted.
   • Gradually withdraw this “scaffolding” in subsequent assigs.

   • Do something very similar for the “expert” reporting process.
     - A second facilitated workshop.
     - Add a facilitated peer-review step.
Pros-cons of “complex” rubrics ...

• Criteria ... but not prescriptions.

• Also – staged removal reduces dependence once.

Thoughts or local contexts?
• Rubrics for guidance / feedback / assessment of “high level” expert skills or knowledge?

Step 3: Instructional scaffolding of authentic tasks

*Wisdom can’t be told* ...
Therefore cause students to confront challenging concepts.

Exercise 1 learning goals: Students will ...

– Articulate / discuss steps necessary for carrying out a design project.

– Outline components and key aspects of a design project report.

– Discuss expectations for report sections and corresponding weightings in terms of importance. “Expectations” means answering “how will I know if my work is appropriate?”

– Build, then take home an outline for assignment 1 and report.
Worksheet establishing needs & criteria for tackling & reporting on open ended design projects

A 2nd worksheet: Peer Review with rubric pg1 of 2

Peer review worksheet pg 2 of 2

Do you or a neighbor deliberately address students’ preconceptions about expertise?
“Step 4” ...

Mentoring the graduate teaching assistant (TA):
1) Developing the activities ...
   • TA was the “expert” (engineer AND teacher/grader)
   • STLF overlaid a pedagogic framework onto discipline expertise.
     – Expertise and frameworking
     – Task analysis
     – Active scaffolding to develop design and report writing expertise.
     – And scaffolding to develop expertise at giving and using peer review.
   • STLF guided construction of resources to
     – A) support student learning without simply “telling”.
     – B) develop 2 guided active-learning exercises for the TA to run.
       (not easy for beginners! )
     – C) ensure that resources will help future TAs run exercises then grade efficiently and consistently.

How do you mentor and/or engage TAs in development and delivery?

“Step 4” ...

Mentoring the graduate teaching assistant (TA):
2) Developing TA pedagogic expertise ...
   • STLF ensured resources have a TA’s version with guidelines for running the exercise
   • Worked with the instructor to ensure
     – TA with experience AND enthusiasm was involved
     – Same TA piloted the exercises
     – AGAIN this TA mentored a new TA in a subsequent term.

Project “products”:

Resources
• Generic process guidelines
• Specific design problem guidelines
• Rubrics for 4 design problems (as used during grading )
• An active exercise to explore the design process and reporting
• An active exercise to practice peer review.

Strategies
• Workshop and facilitating strategies
• Grading with rubrics
• Pair up new TA with experienced TA.
Non-engineering science course examples we have supported using similar strategies.

- Expert task analysis and scaffolding:
  - "Reading", "Questioning", presenting – one 2nd year course
  - Framework and corresponding exercises – 2nd, 3rd yr courses in mineralogy and ore deposits
  - Researching a topic and presenting – 3rd year science elective.
  - Field school: Explicit deconstruction of thinking that goes on during field mapping. **This was transformative** for field school instructors!

- Rubrics:
  - Honors thesis,
  - Posters including peer assessment – 2nd, 3rd and 4th yr courses, including a "virtual poster session" in a 4th year fisheries course.

- TA development and mentoring:
  - Four other projects were funded this way
  - We advocate for partnering new TAs with experienced TAs.

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Students’ workloads, 2012 & 2013

- "**Identify one other course you are taking this term _____**."
- "**Compared to that course, was your workload in our’s …**
  - much more / a little more / similar / a little less / much less ?

- Repeat for up to four other courses ...

Similar perceptions of workloads in 2012 and 2013

Workloads and Enthusiasm, 2013 only:

- Workloads – exactly as per 2012.
- Also ...
  "**Compared to that course, was your enthusiasm for our’s**
  - much more / a little more / similar / a little less / much less ?

- Repeat for up to four other courses ...

More work than other courses

AND

More enthusiasm for this course.

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Results, or impacts of efforts.

**Project evaluation challenges:** Little data from before the initiative.

- Copies of student work not kept from past years.
- Grading **comments** were kept from 2011/.
- Grades? Commonly not a useful measure of innovation or impact.

**Artifacts from this project:**

- Workshop activity worksheets, with documented strategies for TAs.
- Rubrics with TA feedback
- Peer review worksheets
- End of year survey in the first pilot year.
- Student Learning Experiences Survey (SLES) in all EOAS courses for 2013
- Workloads relative to other courses
- Enthusiasm relative to other courses
- Direct feedback from TA.
Perception questions 2012; - Sorted by “agree”

Peer review, 2012

• Generally well received but not as strongly “endorsed” as other aspects.
• Therefore ... should we ...  
  – Improve relevance and motivation? 
  – Mitigate against “unhelpful” peer reviews?

2013: Learning Experiences Survey  highlights:

“How important was each of the following for helping you succeed in this course” ... 40 items: information | classroom | homework.

• Examples: “Extremely or Very helpful” were ...
  – Rubrics
  – Projects (solo and group) 
  – Feedback (intermediate and final) 
  – Studying in groups

• Also, 
  – Learning goals, work done and content were all “clearly related” 
  – This course was “important to me or my degree”

• These data can be shown if interested.
TA – feedback

- Grading is more efficient and consistent (and “easier”)
- Engaging with students feels more like “being a scientist” or “doing science” (or engineering).
- I learned a lot about how people learn!
- Recipient of the 2013 EOAS Teaching Assistant Award: “To formally recognize the outstanding contribution of Teaching Assistants in the delivery of EOS undergraduate courses.”

Further questions and ideas

- “Transfer” of new skills has not been explicitly tested.
  Ideas:
  - Has capstone work of these students improved?
  - Explore further removal of scaffolding for the final design project.
  - Align exam work with scaffolded skills by using instructions that are either explicit, suggestive, or un-aided.
- Comprehensive comparison of before / after initiatives was not done. We applied previously “proven” Research Based Instructional Strategies (RBIS), i.e. our effort was not so much education “research” as development using best practices.

How applicable are ideas in your settings? How sustainable are such strategies?

- Deconstruction of expertise.
- Scaffolding – guidelines, rubrics, workshop strategies.
- Engaging TAs in the process.

Thank you – and thanks to organizers 😊
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   http://writing.colostate.edu/guides/documents/ce-trpt/index.cfm
   EOSC433 points to this explanation on technical report writing.
   Am. J. Phys. 80 (11).
12. In EOAS: common and diverse use of projects:
13. AACU’s collection called VALUE (Valid Assessment of Learning in Undergraduate Education) Rubrics:
   http://www.aacu.org/value/rubrics/index_p.cfm
   http://www.cmu.edu/teaching/assessment/assesslearning/rubrics.html
16. Search Amazon or Google for “rubrics” – there are many many resources and examples out there!