Scholarship of Teaching & Learning and Process Education
Working Towards a SOTL Project

Aligning our perspectives: Where would you like to go on your SoTL journey?

Some initial planning: Thinking about SoTL project design

1. What knowledge, skills, and behaviors am I trying to help my students improve?

   My students struggle with the concept/process of ____________________

2. Can I relate the knowledge, skills, and behaviors I'm trying to improve to specific learning objectives of a "size" that can be reasonably addressed? If so, what are they?

   At the end of this course, my students will be able to ____________________

3. How do I currently address this aspect of learning in my course?

   I use the following teaching technique(s) to help my students: ____________________

4. What assignments or other tools might I use or adapt to collect data about my student's learning for this concept/process?

   Assignment 1 ____________________ *Assignment 2* ____________________

   Survey ____________________

   Other evidence I can study ____________________

5. How might I analyze the data I collect about student learning?

Quantitative approaches?	*Qualitative approaches?*
______________________	______________________
______________________	______________________

Moving forward on your SoTL journey:

1. What are the one or two items from today that can most help you move forward?

2. What is the most important question/barrier remaining in moving your project through the planning stages?

Questions to consider if you are planning to publish your SoTL project:

1. Is there relevant literature in this area that I can use to support and connect to my ideas?
2. How will the project be implemented and presented to the IRB?
3. Will the knowledge and skills I develop for this project be transferable to other contexts? Will they increase my overall efficiency or be synergistic?
4. Who can I work with where opportunities for benefits to both sides exist? In what other ways or to whom might this data be useful?
5. If this project proves successful, who should know? Who will benefit? How easily can others use the techniques/results?

Scholarship of Teaching & Learning and Process Education

A workshop facilitated by
Dr. Tris Utschig
Assistant Director, Office of Assessment, Georgia Tech

Process Education Conference 2015
June 25-27, 2015

1

Getting it better and publishing too

Examples of publicly shared SoTL work:

1. Campus panel discussion – problem-solving rubric
2. Conference poster – student reflection
3. Conference paper – process-oriented learning
4. Journal paper – learner development

4

Question – how do you know your students have learned what you really want them to know or be able to do in your classes?

Planned Workshop Outcomes

By the end of this session, I expect you will:

- Be able to list at least 3 new potential mechanisms for collecting data about learning
- Have created an outline of a potential SoTL project
- Be able to locate at least two helpful online resources and/or print resources
- Show how you might personally use one or more tools/techniques for both assessment and SoTL

Performance criterion – complete activities for a potential SoTL project with a particular course or learning activity in mind while using your colleagues to elevate the quality of your results

5

Both SoTL and assessment are not about getting it right, but getting it *better* !

Assessment is the systematic collection, review, and use of information about educational programs undertaken for the purpose of improving student learning and development

-Ted Marchese

The Scholarship of Teaching and Learning is a systematic reflection on teaching and learning made public

-Illinois State University

The process of measuring and analyzing performance to improve a future performance.

- Apple and Utschig, IJPE vol 1

Activity

- **How do your own goals for today align with the goals for this session?**
  - Be able to list at least 3 potential mechanisms for collecting data about student learning which you have not personally tried before
  - Have created an outline of a potential SoTL project related to data collected about student learning in your classroom
  - Be able to locate at least two helpful online resources and/or print resources
  - Show how you might personally use one or more tools/techniques for both assessment and SoTL

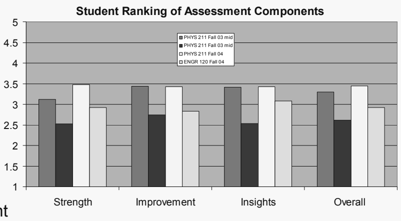
6

Activity: aligning our perspectives

- Please take a minute or two and write down on your handout under "aligning our perspectives" where you would like to go on your journey as a teacher and/or why you decided to participate today
- You may also want to complete the first boxed question on your sheet
- We will share a few volunteer responses

My first "innovation" was a simple student self-assessment of their performance in lab

- 5-15 minutes at end of 3-hour lab period
- SII format
  - Strengths
  - Areas for improvement
  - Insights



My work in SoTL has developed along two foci: my students & interests of other faculty

http://www.fctl.ucf.edu/events/winterconference/

1. Reflection - developing a focus on student learning
2. Reflection - working with other faculty
3. Assessment - expanding my SoTL outlook and toolkit
4. Assessment & research - working with external constituents

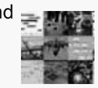
The focus of my assessment and evaluation system eventually was completely changed.

Student learning content

- Individual HW problems
- Exams
- Individual lab reports

Professional engineer using content

- Problem solving portfolio
- Free-writing and assessment
- Exams
- Team lab reports



http://mrmaloney.com/mr_maloney/honors/h_handouts.html

http://en.wikipedia.org/wiki/Portal:Systems_science/Pictur

Scholarly Teaching *significantly* increased my overall productivity as a faculty member

- Example: ~600 hrs/yr gained from reduced grading time
- Example: alignment of skills with program and institutional needs

online.mpls.k12.mn.us

Question – if you were to design a SoTL project for your class right now, what would you do?

Both SoTL and assessment are not about getting it right, but getting it *better* !

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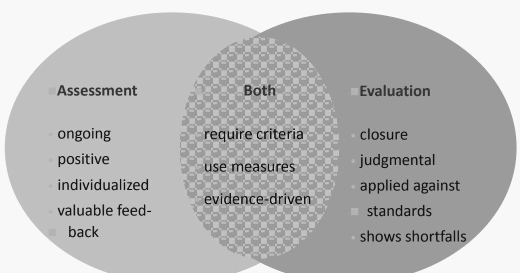
My focus on student learning began with a look at "assessment" rather than "evaluation"

Process for improving a future performance | Process for determining level at which standards were met



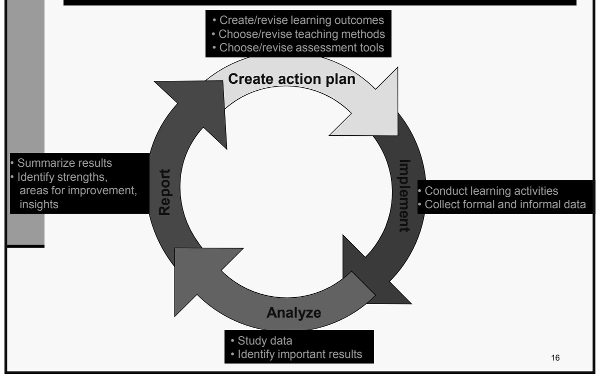
Taken from the Faculty Guidebook published by Pacific Crest

Assessment, evaluation, and SoTL work use similar methods but for very different purposes

Assessment –	Evaluation –	SoTL –
The *process* of measuring and analyzing a performance *for* the purpose of ***improving a future performance***	The *process* of measuring a performance against a set of standards ***to determine the level at which*** the ***standards were met***	A systematic [process of] [evidence based] reflection on teaching and learning [responding to a research question] made public

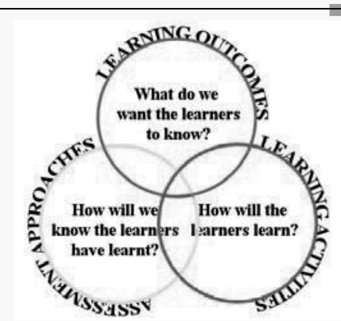
15

The assessment process is cyclic



16

Quality classroom assessment is constructively aligned in a course



Source: Assessment Resource Center at Hong Kong University: http://arc.caut.hku.hk/ConsAlign.html

17

Activity

- **Box 1 on handout –**

  what outcome(s) am I trying to help my students improve?

18

Quality measurable learning outcomes are S.M.A.R.T.

Properties of quality outcomes

- Have a clear and ***S**pecific* purpose
- Result in ***M**easureable/observable* products/behaviors
- Use ***A**ction words*
- Describe ***R**elevant* and meaningful learning
- Are ***T**ime-bound*

19

By the end of this course, students will be able to…

lower order thinking skills → higher order thinking skills

remember	understand	apply	analyze	evaluate	create
recognize	interpret	implement	differentiate	check	design
list	summarize	carry out	organize	debate	construct
describe	infer	use	parse	critique	plan
identify	paraphrase	execute	attribute	experiment	produce
retrieve	classify	teach	outline	judge	invent
name	compare	draw	deconstruct	test	devise
locate	contrast	compute	integrate	detect	make
find	explain	show	select	monitor	hypothesize

Adapted from: http://www.maxvibrant.com/bloom-s-taxonomy/bloom-s-taxonomy

20

Example outcomes

- Conduct an interview of a family member for the purpose of analyzing the origins of one's own political views
- Compare and contrast the value of three different novels as they apply to current issues of social justice.
- Identify unknown bacteria using gram stain, biochemical, and other microbiological methods for identification.
- Given a set of data, construct a time series, scatterplot, or histogram to show relationships between quantities.

21

Activity

- **Box 2 on your handout –**

  Given the area your students are struggling with in your course, write a S.M.A.R.T. Outcome to describe it.

- **Box 3 on your handout –**

  What are you currently doing to address this outcome?

22

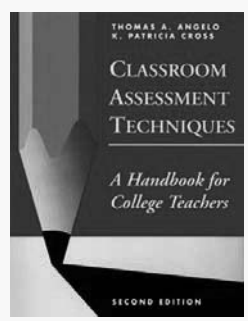
Measuring your outcomes: common assessment and evaluation techniques

- Written exams
- Oral exams
- Performance assessments
- Homework assignments
- Oral presentations
- Projects

- Demonstrations
- Case studies
- Simulations
- Portfolios
- Juried activities with outside panels
- Standardized tests

23

Measuring your outcomes: Classroom Assessment Techniques (CATs)



24

Using classroom assessment techniques for SoTL work has distinct advantages

- Authentic: Students are already being assessed as part of the course
- Flexible: Many different types of assessment can be used
- Transparent: Criteria for success clear to both students, faculty, and outside constituencies

25

Three criteria underlie successful classroom assessment techniques

- Collect feedback from ALL students
- Analyze the results
- Report back to students

Credit – Christina Petersen, University of Minnesota

Measuring your outcomes: direct classroom assessment techniques

- Background knowledge probe
- Focused listing
- Think-pair-share
- Minute Paper
- Directed Paraphrasing
- Documented Problem Solutions

Web resource:
http://www.cetl.gatech.edu/sites/default/files/handout3%20-%20CATs_1.pdf

Poll: I have used at least one of these techniques before – Yes/No

27

Measuring your outcomes: indirect classroom assessment techniques

- Course-related self-confidence surveys
- Group-work evaluations
- Classroom quality circles
- Classroom opinion polls
- *Midterm assessment (not an exam or quiz…)

*Web resource:
http://www.cetl.gatech.edu/cios/midterminfo

Poll: I have used at least one of these techniques before – Yes/No
Poll: I have used a midterm assessment before– Yes/No

28

Activity

- Think-pair-share
- On your handout – please take a few moments to finish answering the boxed questions (Box 4 and Box 5)
- **Wait** for my prompt and then pair with a neighbor to discuss your ideas
- In a few minutes I will ask for several volunteers to share

Assessing the whole: use multiple data streams to create an assessment matrix

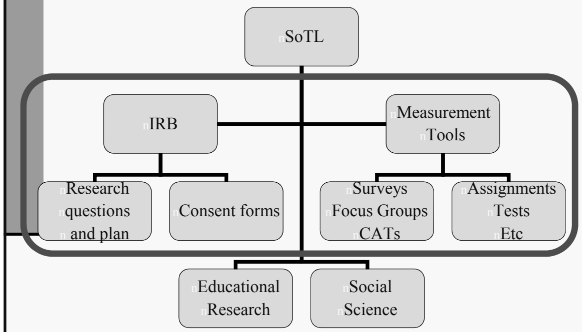
Assessment data streams	Course Learning Outcomes					
	Outcome a	Outcome b	Outcome c	Outcome d	Outcome e	Outcome f
Data 1	x		x	x		
Data 2		x			x	x
Data 3	x			x		x
Data 4		x	x			
Data 5			x		x	

30

2. My second phase of SoTL development occurred via working with my colleagues

- Peer coaching
- Course design
- SoTL Journal Club

4. My current position involves a research focus

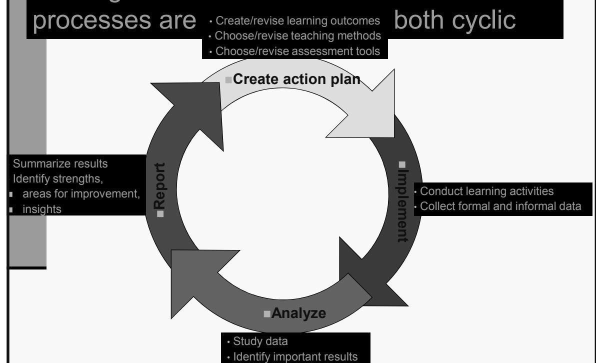


Peer coaching was very valuable for me & others at Lewis-Clark State College

- Context – Division of Natural Science
  - 6 majors
  - 12 programs
  - 21 line numbered faculty
  - Significant service load

- Goals
  - Peer coaching part of assessment culture
  - Improve assessment practice
  - Improve teaching practice and learning outcomes
  - Increase sense of community

Coming full circle: the SoTL and assessment processes are both cyclic

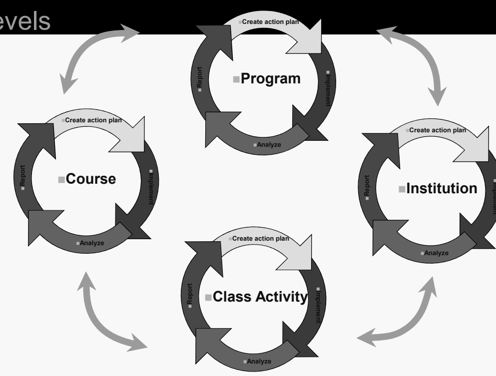


A more recent development is the SoTL Journal Club (meets ~6 x/yr), and you are invited!

- What is SoTL
- SoTL case study
- Testing formats
- Using teams
- etc.

http://ozandends.blogspot.com/2008_08_01_archive.html

Both SoTL and assessment occur at various levels



Resources

37

More resources

- NC State University: Internet Resources for Higher Education Outcomes Assessment
  - http://www2.acs.ncsu.edu/UPA/archives/assmt/resource.htm
- 50 Classroom Assessment Techniques Summary
  - http://pages.uoregon.edu/tep/resources/newteach/fifty_cats.pdf
- Western Washington University
  - http://pandora.cii.wwu.edu/cii/resources/
- National Science Foundation
  - http://www.flaguide.org

38

Closure Activity

- With your group, please discuss among yourselves one or both of the following from the back of your handout
  - What are one or two items from today (not just from this session) that will help you move forward on your SoTL journey?
  - What is most important question/barrier remaining that might prevent you moving forward on your SoTL journey?
- In a few minutes I will ask for several volunteers to share

Feedback

- **Minute paper**
  - **What was the most important thing you learned in this session?**
  - **What important question remains unanswered?**

40

Thank You!!!

Contact information:

- tris.utschig@gatech.edu

41

The End

42

Problem Solving Rubric (Grading Guide) NRE 4214 A Fall 2014 Name ____________________________

	Level 5 Quality Problem Solver	**Level 4** Effective Problem Solver	**Level 3** Maintenance Problem Solver	**Level 2** Survival Problem Solver	**Level 1** Novice Problem Solver
Completion	All problems contain complete solutions with all relevant information presented such that solutions are fully communicated	Attempts nearly every problem and solutions generally contain all or most of the relevant information	Attempts many problems and usually lays out nearly complete solution plans for each problem attempted	Majority of problems are attempted with some components of solution communicated	Perhaps attempts half the problems with wildly varying levels of completeness
Clarity and Organization	Problems clearly labeled by topic and in order. Excellent use of white space for easy perusal with clearly indicated solution components	Problems labeled and easy to find. Good use of white space but sometimes cramped or too many pages or components out of order	Problems mostly labeled and collected together. Work has proper components but may be difficult to distinguish solution parts	Work is loosely together but specific problems hard to find White space may be lacking, lacks ques to lead reader through the problem solution	Work collected haphazardly, mixed with other materials, etc. Messy work that is hard to follow and often missing solution components
Communica-tion of solution	Prob statmnts in own words isolate physics of problem briefly, correctly, completely Diagrams are large, descriptive, neat and completely labeled Steps to solution succinctly described in logical order along with relevant governing equations Mathematical manipulations follow clear steps, perform appropriate amount of algebra before plugging in numbers Work is technically flawless Correct units are always shown and conversion work is included Deep thinking evident in discussion	Prob statmnts in own words describe physics of problem clearly Diagrams show physical situation and include labels Steps to solution labeled, follow logical order, and governing equations written out Mathematical manipulations mostly easy to follow but may show too much or too little algebraic detail befor plugging in numbers Work is nearly all technically correct Correct units are used and converted consistently as needed Insightful discussion sheds light on topic	Prob statmnts mainly repeat book statmnts & do not show much original thought Diagrams included but lack some labels, details, or clarity Steps to solution are present but often lack explanations of procedure and/or governing equations Mathematical manipulations sometimes combine too many steps or skip steps and plug numbers in before algebra is complete. Some technical errors are present Units used for at least part of problem and conversions sometimes shown Accurate,meaningful discussion	Prob statmnts often missing, incomplete, or even incorrect Diagrams minimal and only used from book or if easy to do Steps to solution unclear and usually lack explanations of procedure and/or governing equations Minimal mathematical manipulations and numbers usually plugged in right away - checking work is difficult Technical errors are common Units included in answer & sometimes elsewhere. Skipping conversions common Basic discussion repeats core ideas	Prob statmnts usually skipped to save time, omit information, and contain errors Diagrams usually skipped to save time and effort in writing. Steps to solution not identified, governing equations not written out, and work does not have logical flow Problem is worked by going straight to plugging in numbers with algebra done last and numerous Errors severe – does not model problem Units maybe in answer, rarely elsewhere. Conversions skipped Flawed discussion or just repeats answer

Midterm _______ or Final ________

Aggregate grade based on above categories: Percent ________ Letter __________
(note: completion serves as multiplier)

Problem Solving Performance Criteria for Homework:
You will be able to effectively present complete problem solutions to real world reactor engineering applications through a clear, organized approach that fully presents the problem setup, path(s) to solution, and relevant analysis while paying careful attention to detail through use of informative diagrams, guiding notes, general governing equations, proper mathematical techniques, consistent use of units, and reflective thought.

Basic Parts of Quality Problem Solutions (these can be used in a variety of successful combinations)

- Problem Statement
- Labeled Diagram
- Given Information and Assumptions
- Descriptive Solution Path
- Governing Equations
- Mathematical Analysis with Units
- Discussion

Sample Formats involving one or more pages for each problem

<table>
<tr><td>Problem statement and Given Information</td><td>Diagram(s)</td></tr>
<tr><td colspan="2">Assumptions</td></tr>
<tr><td colspan="2">Step1 description & governing equations
Step1 analysis/calculations</td></tr>
<tr><td colspan="2">Step2 description & governing equations
Step2 analysis/calculations</td></tr>
<tr><td colspan="2">Step3 description & governing equations
Step3 analysis/calculations</td></tr>
<tr><td colspan="2">Step4 description & governing equations
Step4 analysis/calculations</td></tr>
<tr><td colspan="2">discussion/reflection</td></tr>
</table>

<table>
<tr><td>Problem Statement

Given Information</td><td rowspan="3">Steps to solution
• Governing Equations
• Analysis/Calcs
• Discusion/reflection</td></tr>
<tr><td>Assumptions</td></tr>
<tr><td>Diagram(s)</td></tr>
</table>

Portfolio FAQs

1. **Can I turn in my work to get feedback at times other than the official collection points?**

   Yes. At any time you can turn in your work and pick any two areas on which you want feedback (use of units, drawing diagrams, performing mathematical manipulations, layout of problems, writing strengths, describing why a strength is important, suggesting action plans for areas of improvement, etc.).

2. **Is my grade fixed for the material turned in once the rubric is applied?**

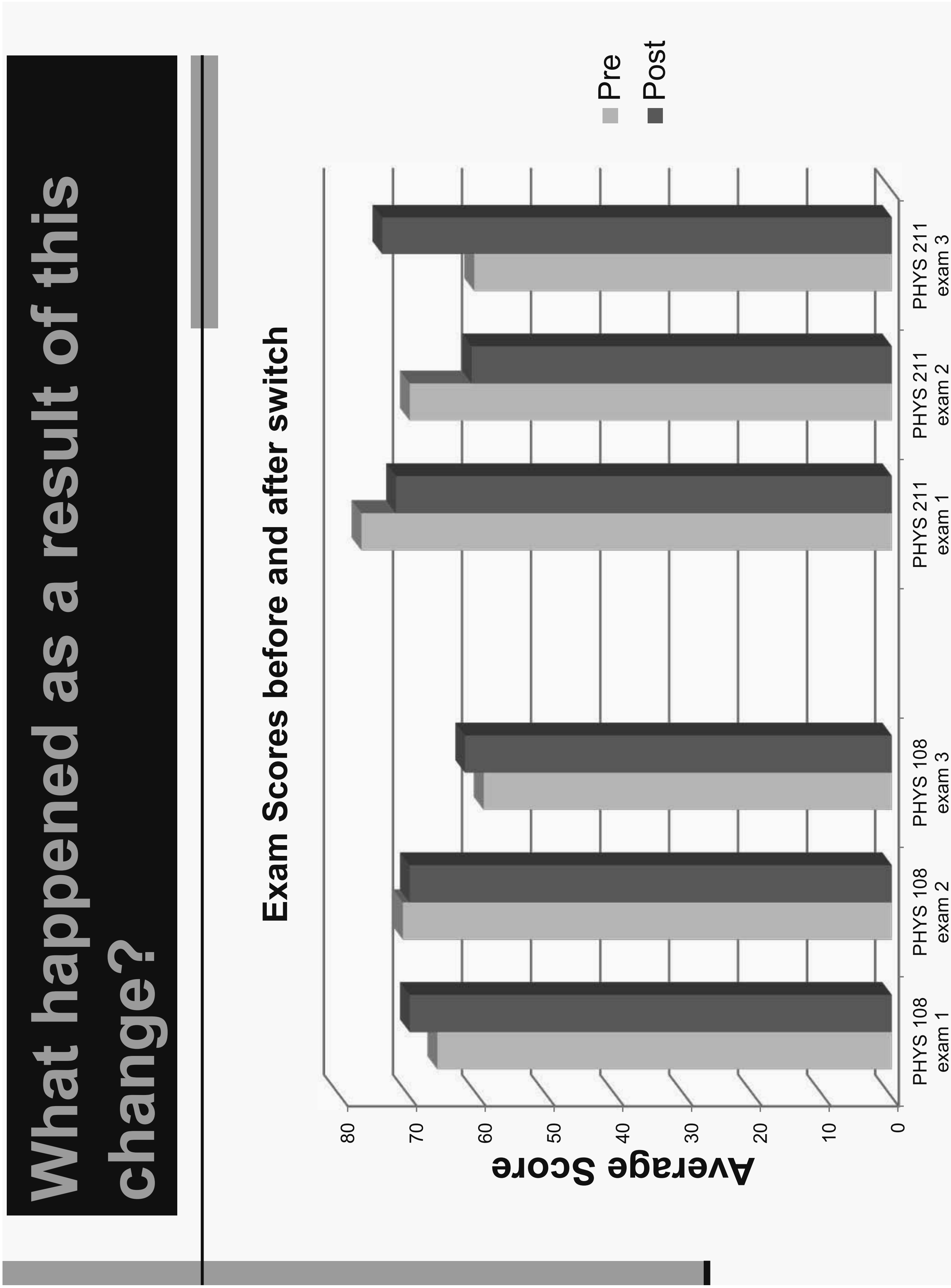
   No. The HW rubric grade will change if you improve the quality of your work.

3. **Am I allowed to add material and fix mistakes on old hw problems in addition to improving by doing better on future assignments?**

   Yes. You can continue to work on old problems until you are satisfied with your performance on them. Adding diagrams, improving problem statements, fixing mathematical errors, etc are all OK. Making these changes clearly visible will make it easier for the instructor to see your progress.

4. **How does the additional feedback work if I turn things in between official collection periods?**

   The instructor will give you feedback in the form of an SII addressing the 1-2 areas you chose to focus on. This in no way counts towards your grade. It is purely for you to use in recognizing your strengths and improving the quality of your work.


What happened as a result of this change?
Exam Scores before and after switch
Average Score
0
10
20
30
40
50
60
70
80
PHYS 108 exam 1
PHYS 108 exam 2
PHYS 108 exam 3
PHYS 211 exam 1
PHYS 211 exam 2
PHYS 211 exam 3
Pre
Post

Georgia Institute of Technology

Favorite Innovation:

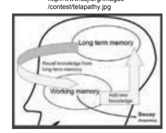
Student Journaling – Periodic Free-writing Prompts and a Rubric for Student Entries

Tristan T. Utschig
Center for the Enhancement of Teaching and Learning
&
Mechanical/Nuclear Engineering

Georgia Institute of Technology

What are the benefits?

http://www.csj.org/images/contest/telapathy.jpg



http://www.edukatetodd.com/activelearning

* Additional learning mode
* Active learning
* See student view of key concepts
* Move towards deep learning, not surface

Georgia Institute of Technology

What is it?

Students write a paragraph or two on a variety of instructor-chosen aspects regarding their learning and performance in my course.

Georgia Institute of Technology

Why I got started?

Students often lack practice communicating in writing in their own words about technical course content.

Want to increase fluency and understanding together.

Georgia Institute of Technology

How do you implement it?

1. Create rubric for grading student free-writes
2. Each week choose a critical content item or process
2. Prepare handout each time with
   - One sentence question prompt
   - A helpful hint on how to approach their written response
3. Use 5-7 min. each week in class to complete
4. Students collect work in journal
5. Provide periodic feedback (assessment of their journal contents)
6. Evaluate student portfolio w/ rubric at end of course

Georgia Institute of Technology

What resources are on display?

* Rubric
* Example free-writing prompts

http://moodletraining.blogspot.com/2007/07/handouts-to-videos.html

Free-writing Question Prompt

(for your HW journal)

- How have you usually dealt with units when performing engineering analysis in previous courses and how might you improve this practice during the course of this semester?

- Showing a simple example involving force, pressure, or temperature might help.

Free-writing Question Prompt

(for HW Journal)

- How are power cycle efficiency and the refrigeration/heat pump coefficients of performance related?

- Including the general principles from which they can be derived along with their equations and any similarities/differences may be helpful.

Free-writing Question Prompt

(for HW Journal)

Describe your process for using the property tables at the back of the textbook in order to determine the phase state of a substance and then determine needed values for specific volume, specific internal energy, etc.

Listing the steps you use to determine the relevant information and including as many specifics as possible (perhaps even an example with numbers) will help you get the most value from this exercise.

Free-writing Question Prompt

(for HW Journal)

How does the Clausius equation introduced at the end of Chapter 5 relate to the entropy rate balances discussed in Chapter 6?

Listing the equations, discussing their similarities and/or differences, and discussing under which conditions they are relevant may be one straight forward approach.

Free-Writing Journal Rubric (Grade Determination Guide)
Mechanical Engineering 3322 B – Thermodynamics, Fall 2008

Name ______________________

	Level 5 Expert Journal Writer	**Level 4** Effective Journal Writer	**Level 3** Maintenance Journal Writer	**Level 2** Survival Journal Writer	**Level 1** Novice Journal Writer
Completion and Organization	All free-writes are complete Each journal entry has your name, the date, and a subject line along with the journal entry	Nearly all free-writes are complete Nearly all journal entries have your name, the date, and a subject line along with the journal entry	Most free-writes are complete Most journal entries have your name, the date, and a subject line along with the journal entry	Free-writes are often missing or half finished Few journal entries have your name, the date, and a subject line along with the journal entry	Many free-writes are missing or half finished Rarely do journal entries have your name, the date, and a subject line along with the journal entry
Free-writing	Content is always accurate Deep thinking is evident and content relates to learning the topic Specific information is included to supplement generalizations	Content is quite accurate Content applies to the subject at hand and help shed light on learning the topic Sometimes generalizations are applied with specific instances	Content reflects moderate understanding of topic Content applies to subject but often just repeat information from class Content is usually either general or specific but not both	Content has many mistakes that could easily be fixed in minimal time Content may contain appropriate language but are not refined to aid learning Content generally sticks to broad definitions without connecting to applications	Content is hard to follow or make sense of Content shows little evidence of learning the material Content cannot connect general topic to specific applications due to misconceptions

Midterm _______ **or Final** ________

Aggregate grade based on above categories: Letter ________ **Percent** __________

Process-oriented Approaches in Content-Intensive Courses :

Teaching / Learning of Machine Design

Georgia Tech Mechanical Engineering — The George W. Woodruff School of Mechanical Engineering

Raghu Pucha, Steven Liang and Tris Utschig

Georgia Tech Center for the Enhancement of Teaching and Learning

OBJECTIVES

- **Explore** how process oriented approaches influence student learning in "Machine Design".
- **Compare** (1) traditional content-centered approaches with focus on textbook problem solving to (2) process-oriented approaches using prior knowledge of CAD and analytical tools.
- **Quantify** students' performance in the content-centered approach, process-oriented approach, and integrated approach combining content and process.
- **Provide insight** on the effect of various approaches on students' learning attitudes and engagement.

Experimental Setup

	Process Oriented Approach	Content Centered Approach	Integrated Approach
Lectures	Traditional : Discuss concepts, design equations and failure theories	Traditional : Discuss concepts, design equations and failure theories	Traditional : Discuss concepts, design equations and failure theories
Home works	Text-book Problems	Text-book Problems	Process Oriented with CAD and analytical tools (see Appendix 3)
Exam 1	Take-home case-study design problem (see Appendix 1)	Text-book Problems	Text-book Problems
Exam 2	Take-home case-study design problem (see Appendix 1)	Text-book Problems	Text-book Problems
Final	Tex-book Problems	Text-book Problems	Text-book Problems
Team Project	Design and analysis of Mechanical System (see Appendix 2)	No Team Project	Design and analysis of Mechanical System (see Appendix 2)
Use of CAD & Analytical tools	Optional	Optional	Mandatory

Assessment

- Student performance data across section types
  - Exams
  - homework
- Pre and post surveys of student perception
- End of semester course instructor surveys

WHICH IS BETTER?

THIS — Content Centered Approach

A shaft is loaded in bending and torsion such that $M_a = 70$ N · m, $T_a = 45$ N · m, $M_m = 55$ N · m, and $T_m = 35$ N · m. For the shaft, $S_u = 700$ MPa and $S_y = 560$ MPa, and a fully corrected endurance limit of $S_e = 210$ MPa is assumed. Let $K_f = 2.2$ and $K_{fs} = 1.8$. With a design factor of 2.0 determine the minimum acceptable diameter of the shaft using the
(a) DE-Gerber criterion.

Solution from Student

(a) DE-Gerber, Eq. (7-10):

$$A = \sqrt{4(K_f M_a)^2 + 3(K_{fs} T_a)^2} = \sqrt{4[(2.2)(70)]^2 + 3[(1.8)(45)]^2} = 338.4 \text{ N·m}$$

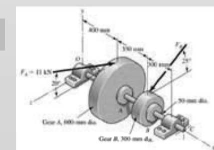
$$B = \sqrt{4(K_f M_m)^2 + 3(K_{fs} T_m)^2} = \sqrt{4[(2.2)(55)]^2 + 3[(1.8)(35)]^2} = 265.5 \text{ N·m}$$

$$d = \left\{ \frac{8(2)(338.4)}{\pi(210)(10^6)} \left[1 + \left(1 + \left[\frac{2(265.5)(210)(10^6)}{338.4(700)(10^6)} \right]^2 \right)^{1/2} \right] \right\}^{1/3}$$

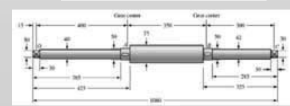
$d = 25.85\,(10^{-3})$ m $= 25.85$ mm *Ans.*

OR — Process Oriented Approach Supporting Prior Knowledge

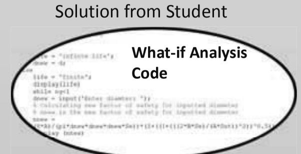
The problem shown in the figure was solved in the lecture. Please check your lecture notes.



(2) The above problem solved in the lecture predicted local yielding and low factor of safety n=0.25. Develop a design code in MATLAB and suggest a suitable diameter for the shaft to achieve infinite life (n>1) and to make sure it won't yield under static loading. Show your calculations with new diameter. (5 points)
a. Generate results for safety factor for yield and infinite life for various diameters and tabulate the results.
b. Show the final layout of the shaft (hand drawn is ok) with the diameter calculated from step a.

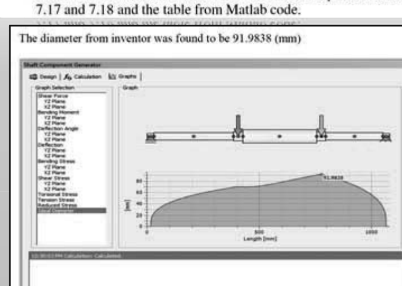


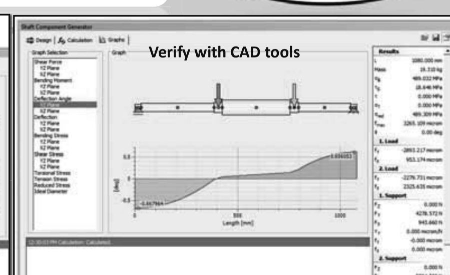
Solution from Student



(3) For this shaft check for minimum deflection and slope using Inventor – Design accelerator and make sure they meet Table 7.2 allowables. If not determine new diameters using equations 7-17 and 7-18. (15 points)
a. show your deflection and the slope diagrams using inventor
b. compare maximum slope and the deflection with the table 7.2 (please pay attention to the units)
c. Recalculate the diameters using equation 7.17 7.18 for slope and deflection respectively.
d. from inventor, show the maximum diameter required and compare with your equation 7.17 and 7.18 and the table from Matlab code.

The diameter from inventor was found to be 91.9838 (mm)



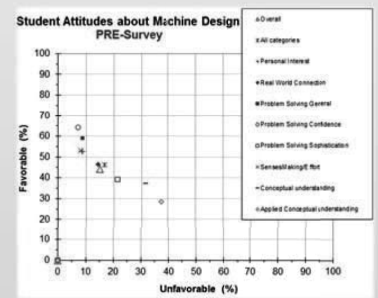


RESULTS

Which approach provides the best results?

Comparison of Student Performance	HW1	HW2	Exam1	HW3	HW4	Exam2	HW5	Project	Final
Process-Oriented Approach - Fall 2011 (N=90)									
Avg. (%)	82.60	60.40	87.81	80.96	73.10	95.87	73.06	85.40	60.64
Sdev	4.63	10.54	16.73	8.24	12.22	5.18	9.78	23.95	10.98
Integrated Approach - Fall 2012 (N=78)									
Avg. (%)	93.60	80.08	83.28	71.70	80.13	81.98	78.66	85.28	71.82
Sdev	3.42	10.06	8.71	10.00	9.52	5.68	11.83	31.94	15.72

How do students feel about the integrated approach?



*"This class has done a great job with relating everything to the **big picture**."*

*"This is the first class I felt would be applicable in **real life situations**. I learned more than I do in most classes due to teaching style."*

*"I know that if tomorrow in any industry I need to design on of the mechanical elements covered in the book, I will be able to **apply my knowledge** and achieve objective."*

*"This class focused **less on memorization** and difficult exams so I was able to focus more on conceptual ideas."*

*"Having to code for HW and the project, I felt that I needed a great knowledge and **understanding of the material**."*

CONCLUDING REMARKS

- Process oriented approaches were well received by students.
- However, the teaching methodology with a primary focus on process oriented activities resulted in worse student performance in traditional time-bound end-of-term exams.
- A more integrated approach combining content-centered and process-oriented elements indicates improved performance.

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Measuring Skills across the Profile of a Quality Learner and of a Quality Engineer

Tristan T. Utschig[1], Sunni M. Newton[1], and Jeffrey S. Bryan[1]

Abstract

We have adapted two previously published profiles to create instruments which measure the attributes represented in the profiles of a quality learner and of a quality engineer on a scale of 1-5. This work is important because it extends the usefulness of the profiles beyond a simple vision or goal state. First, we confirm that the instruments have high face and content validity. Then, we calculate internal reliability coefficients for each of the attributes based on data from approximately 200 students in two different engineering courses. Strong reliability (alpha > 0.7) was found for 12 of the 13 attributes. Next, we compute ranges, averages, and standard deviations among responses for each attribute and find reasonable discrimination among the population tested. We then test the criterion-related reliability of the instrument by correlating ratings for attributes to course and individual assignment grades. Six of the 13 attributes for these two profiles were found to have statistically significant correlations with student grades in the course where the instrument was employed, and numerous significant correlations were found among individual assignments with particular attributes. The attribute of an "achiever" in engineering was most strongly correlated with course and assignment grades. These results imply that quantitative data about student perceptions of skill across the profiles can now be collected and used for program, course, or activity design in order to better achieve learning outcomes and produce high quality graduates. In addition these two instruments can help define for students what critical characteristics they need to develop in order to become excellent learners and engineers. Further, we note that the identified attributes are qualities desirable in many fields. In particular, the instrument for quality engineers, though designed with engineers in mind, is applicable to many fields, needing only minor adjustments to suit the specific needs of the user.

Introduction

We have adapted two previously published profiles—that of a quality learner and that of a quality engineer—to create instruments which measure the degree to which an individual possesses attributes represented in each of those profiles. The instruments ask the user to rate him/herself on a scale of 1-5 for six characteristics (or subscales) of a quality learner and eight characteristics (or subscales) of a quality engineer, where each subscale is measured using several individual items. The instruments are based on the TIDEE profile of a quality engineer (Davis, Beyerlein & Davis, 2005) and on Nancarrow's (2005) profile of a quality learner. Specifically, in this paper we discuss the process of developing the items for these two instruments and attaching a scale to those items.

We then present efforts to ensure that the instruments are both valid and reliable. First, we explore face and content validity by turning to relevant literature. Then, we explore the results obtained from testing the instruments with approximately 200 engineering students. We calculate the internal reliability coefficients for each subscale of the two instruments. We also analyze reported student self-perceptions of their abilities for each subscale. We quantify the average self-reported ratings of freshman and junior-level students on the six quality learner characteristics and eight quality engineer characteristics, and we compare general trends in these data with similar data from other studies. Finally, as a means to explore criterion-related reliability, we correlate students' grades to their ratings of their own abilities. For each subscale we compare the quality learner scale and quality engineer scale results with overall student grades in the courses where the instruments were applied and with grades on selected assignments or parts of assignments in those courses. From these results, we can state that the subscales for these instruments show generally high levels of internal consistency, that student self-perceptions appear to change over time as students move through a program, and that certain subscales of the instruments appear to correlate well with certain types of graded work.

In the last section of the paper, we use our results to discuss specific strategies one might use to help students improve on particular subscales. We also reflect on the overall value of the instruments and how they might be improved through further development and testing. This work greatly extends the usefulness of these two profiles such that quantitative data about student perceptions of skill across the profiles can now be collected and used for program, course, or activity design to supplement other efforts toward better achieving learning outcomes and producing high quality graduates. In addition, these two instruments can help define for students what critical characteristics they need to develop in order to become excellent learners and engineers.

Background

Profiles serve to define the attributes of top performers for specific types of complex tasks. Two profiles, in particular, may be helpful in guiding the development of future

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engineers as they move through their higher education programs. The profile of a quality learner provides a description of attributes which lead to success in the general academic environment where learning is an explicit requirement supporting nearly all academic activities. The profile of a quality engineer provides a description of attributes that will be required for individuals to become top performers in an engineering work environment. Thus, together, the profiles of quality learners and engineers form a useful set of attributes around which an engineering curriculum can be built.

Nancarrow (2005) has this to say regarding the profile of a quality learner:

> Quality learners exhibit definable behaviors that optimize learning and predict successful performance. These behaviors can be classified and assessed. By recognizing these behaviors, learners and instructors can work toward the ideal behaviors, and instructors can design instruction to foster growth in learning behaviors.

The contents of this original profile include six attributes with a total of 34 descriptors comprising these attributes.

Davis, Beyerlein, and Davis (2005) state the following regarding the profile of a quality engineer:

> The profile presents technical, interpersonal, and professional skills or behaviors that align with key roles performed by the engineer. The profile is a valuable resource for educators and for students aspiring to become high performing professionals in the field of engineering.

The contents of this original profile include ten attributes with a total of 50 descriptors comprising these attributes.

The content of these profiles is indeed rich. However, the profiles by themselves simply represent a goal state. We identified that, in order to turn these profiles into readily usable measures that might be applied quickly over a broad spectrum of activities, their contents would need to be simplified, and a rating scale would need to be attached to each of the attributes. These modifications would allow both for tracking of changes in the attributes over time, and for the development of targeted activities to build strengths among the various attributes of the profile.

The instruments have been adapted and simplified from their original form in order to:

- produce a more manageable number of skills to be evaluated in an effort to reduce survey fatigue
- isolate skills most relevant to a typical engineering course in order to encourage adoption by faculty and to resonate with the student experience
- produce a consistent grammatical structure for use in a survey format

The result of this activity produced the two instruments shown in Table 1.

Second, a five point Likert scale was used such that students could easily rate themselves on the items related to each attribute. The scale chosen was applied to each item and has the following structure:

5 = very characteristic of me

4 = characteristic of me

3 = moderately characteristic of me

2 = not really characteristic of me

1 = not at all characteristic of me

This scale is used to rate each item for each attribute. From there, scores on individual items comprising an attribute can be averaged to obtain a score for each attribute.

Literature Survey

Next, we explore the face validity and content validity of the instruments by surveying relevant literature. Significant work regarding the face validity of the instruments was conducted during the development of the original version of the instruments as reported by Nancarrow (2005) in her "Profile of a Quality Learner," and in the "Development and Use of an Engineer Profile" (Davis, et al., 2005). These were presented to multiple user groups in a variety of settings and developed with direct input from those groups. Since the only modifications made to the profiles involved simplification and minor grammatical changes, the face validity of the instruments is assumed to remain high. However, in addition to basing our attributes on those identified by Nancarrow and Davis, et al., we surveyed the literature for similar instruments and compared our attributes to theirs, such that we can also establish a reasonable level of content validity.

We found evidence for identification of high level learner characteristics mirroring those outlined by Nancarrow (2005) in several similar research efforts: the recent book How Learning Works (Ambrose et al., 2010); a study on self-efficacy and learner competencies for homework practices (Bembenutty, 2011); and a study on adult learners (Spigner-Littles & Anderson, 1999). Similar studies on growing learner competencies have also been completed, including investigations of undergraduate learning interventions (Norton, Scantlebury, & Dickens, 1999); the learning styles and strategies of language learners (Wong & Nunan, 2011); and learners of English as a foreign language (Jing, 2010). Not only did these studies employ a similar methodology by seeking self-reported data,

International Journal of Process Education (June 2012, Vol 4 Issue 1)

Table 1 Adapted profile attributes and individual items for quality learners and engineers*

Adapted Profile of a Quality Learner (5 attributes, 20 total items)

Information Processing
- Accesses information quickly
- Distinguishes relevant from irrelevant information
- Learns new tools and technologies to facilitate learning

Values
- Has a vision for life and can articulate goals and objectives with measurable outcomes
- Uses learning to clarify personal value system
- Respects and values the difficulty and importance of learning
- Approaches new tasks with confidence in ability to master new learning

Learning Skills
- Takes responsibility for his or her own learning process
- Demonstrates interest, motivation, and desire to seek out new information, concepts, and challenges
- Validates own growth and understanding without the need for outside affirmation
- Actively seeks out ways to improve learning skills
- Integrates new concepts within a general systems perspective

Intrapersonal Skills
- Focuses energy on the task at hand
- Perseveres through difficult tasks, making good decisions about when to seek help
- Uses failure as a frequent and productive step on the road to success
- Assesses goals and makes appropriate changes to reach them

Thinking Skills
- Clarifies, validates, and assesses his or her understanding of concepts
- Applies concepts to new contexts
- Transfers and synthesizes concepts to solve problems
- Takes appropriate action to get back on track when the planned path is blocked or ineffective

Adapted Profile of a Quality Engineer (8 attributes, 26 total items)

Analyst
- Searches strategically to identify all conditions, phenomena, and assumptions influencing the situation
- Identifies applicable governing principles of mathematics, natural sciences, and engineering sciences
- Extracts desired understanding and conclusions consistent with objectives and limitations of the analysis

Problem Solver
- Examines problem setting to understand critical issues, assumptions, limitations, and solution requirements
- Considers all relevant perspectives, solution models, and alternative solution paths
- Validates results, interprets and extends the solution for wider application

Designer
- Searches widely to determine stakeholder needs, existing solutions, and constraints on solutions
- Thinks independently, cooperatively, and creatively to identify relevant existing ideas and generate original solution ideas
- Synthesizes, evaluates, and defends alternatives that efficiently result in products (components, systems, processes, or plans) that satisfy established design criteria and constraints to meet stakeholder needs

Researcher
- Formulates research questions that identify relevant hypotheses or other new knowledge sought
- Plans experiments or other data gathering strategies to address questions posed and to control error
- Interprets and validates results to offer answers to posed questions and to make useful application

Communicator
- Prepares a message with the content, organization, format, and quality fitting the audience and purpose
- Delivers a message in a timely, engaged, and credible fashion that efficiently achieves desired outcomes
- Assesses the communication process and responds in real time to advance its effectiveness

Collaborator
- Respects individuals with diverse backgrounds, perspectives, and skills important to the effort
- Values roles, accepts role assignments, and supports others in their roles
- Contributes to development of consensus goals and procedures to promote effective cooperation
- Resolves conflicts to promote enhanced buy-in, creativity, trust, and enjoyment by all
- Contributes to and accepts feedback and change that support continuous improvement

Self-Grower
- Takes ownership for one's own personal and professional status and growth
- Defines personal professional goals that support lifelong productivity and satisfaction
- Regularly self-assesses personal growth and challenges to achieving personal goals

Achiever
- Accepts responsibility and takes ownership in assignments
- Maintains focus to complete tasks on time amidst multiple demands
- Takes appropriate actions and risks to overcome obstacles and achieve objectives

* All items presented to participants were grouped into the categories as shown in the questionnaire and were not randomized or scattered. Any potential bias introduced to the instrument as a result of this grouping was not investigated.

but they also found high level learner competency traits similar to those identified by Nancarrow (2005).

Likewise, in regards to competencies associated with engineering, we reviewed a study evaluating employer perspectives on desirable engineer skills (Lohmann, Rollins & Hoey, 2006); one that projected characteristics that engineers will need in the future (Robinson, Sparrow, Clegg, & Birdi, 2005); a study of engineering aptitudes (Harrison, Hung, & Jackson, 1955); and one that explored the personality profiles from past engineers (Harrison, Tomblen, & Jackson, 1955). All pointed to general characteristics similar to those identified by TIDEE (Davis, et al., 2005) as well as characteristics we focused on for our research, namely, those having the titles "analyst," "problem solver," "designer," "researcher," "communicator," "collaborator," "self-grower," and "achiever." Each study used similar evaluation methods, either seeking self-reported data as we did, or gathering experts to identify common characteristics as TIDEE had done, identifying several universally consistent engineering competencies, or competencies toward which engineers should aspire.

In terms of face validity, then, given the similarities between our two instruments and those of others measuring the same or similar attributes, we feel confident that we have created a process-based tool that appears to measure the attributes of a quality engineer and a quality learner that we believe it to be measuring. Further, our general approach to developing profile attributes by developing engineer and learner characteristics is validated by all of the research we surveyed that used measurement instruments similar to our own and which yielded measurements similar to our own. Robinson, Sparrow, Clegg, and Birdi (2005) put it best: "differences between excellent and adequate performance [among engineers] are more likely to be a result of differences in the level of personal attributes, project management skills, and, to a lesser extent, cognitive strategies and cognitive abilities," and therefore instruments affecting improvement on those skills may be used in conjunction with targeted activities to help grow competent engineers.

Results

Instrument Analysis

Reliability of Internal Consistency

One major aim of this research effort was to assess the functionality of the learner and engineer profile instruments among several distinct samples of undergraduate engineering students. Reliability of internal consistency is a key criterion for evaluating the instrument, as this metric allows us to assess how well the items in a given scale "go together," or tap a single construct rather than multiple, related constructs. Cronbach's alpha values were calculated for each of the 13 attributes or scales (5 for learners and 8 for engineers) in order to assess the reliability of internal consistency of these two instruments (see Table 2). Given that the alpha values should not be expected to vary by class standing, the four freshman groups and one junior group were combined into a single sample for this analysis, resulting in a sample size varying from 149 to 163 (Ns vary due to missing data from some students on some subscales). In their 1994 book, Nunnaly & Bernstein offer a generally acceptable cutoff of alpha ≥ 0.70 for analyses completed "in the early stages of predictive or construct validation research." Using this cutoff, all but one of the 13 profile scales (information processing) exceed this value and as such all but one have acceptable alpha values within this sample.

Table 2 Cronbach's α values for 13 profile scales, combined (freshmen & juniors) sample

Scale	N	alpha	# items
Information Processing	163	0.559	3
Values	159	0.797	4
Learning Skills	159	0.8	5
Intrapersonal	160	0.74	4
Thinking	161	0.799	4
Analyst	148	0.72	3
Problem Solving	149	0.778	3
Designer	147	0.782	3
Researcher	148	0.906	3
Communicator	148	0.885	3
Collaborator	149	0.818	5
Self-Grower	149	0.773	3
Achiever	149	0.794	3

Basic Results

The next step in assessing the overall functionality of these instruments was to calculate ranges, means, and standard deviations for the freshman and junior samples. These data are presented in the two tables on this page (Table 3 for the four freshman samples combined, and Table 4 for the junior sample). The minimum and maximum values in the tables here represent a single student's average rating across each descriptor associated with that attribute. Thus, we see decimals for the minimum values. For the maximum values at least one student rated him or herself at the highest level for each descriptor associated with an attribute, and thus each

International Journal of Process Education (June 2012, Vol 4 Issue 1)

Table 3 Ranges, means, and standard deviations for the freshman sample (4 semesters combined)

Attribute Name	N	Minimum	Maximum	Mean	Std. Deviation
Information Processing	129	2.33	5.00	4.03	0.56
Values	127	1.50	5.00	4.13	0.69
Learning Skills	125	2.20	5.00	3.95	0.64
Intrapersonal	127	2.00	5.00	3.88	0.71
Thinking	127	2.25	5.00	4.05	0.63
Analyst	118	2.33	5.00	3.95	0.64
Problem Solver	119	1.67	5.00	3.87	0.76
Designer	117	1.67	5.00	3.73	0.75
Researcher	118	1.33	5.00	3.74	0.86
Communicator	118	2.00	5.00	3.92	0.81
Collaborator	119	2.40	5.00	4.33	0.61
Self-Grower	119	2.33	5.00	4.22	0.69
Achiever	119	2.00	5.00	4.25	0.70

Table 4 Ranges, means, and standard deviations for the juniors sample

Full Scale Name	N	Minimum	Maximum	Mean	Std. Deviation
Information Processing	34	3.00	5.00	3.95	0.58
Values	32	2.00	5.00	3.90	0.80
Learning Skills	34	2.00	5.00	3.89	0.73
Intrapersonal	33	2.00	5.00	3.64	0.82
Thinking	34	2.50	5.00	4.05	0.67
Analyst	30	2.67	5.00	3.91	0.67
Problem Solver	30	2.00	5.00	3.70	0.82
Designer	30	2.00	5.00	3.66	0.80
Researcher	30	1.00	5.00	2.96	1.17
Communicator	30	2.00	5.00	3.72	0.83
Collaborator	30	2.80	5.00	4.21	0.62
Self-Grower	30	2.00	5.00	4.06	0.87
Achiever	30	2.00	5.00	4.07	0.83

maximum is listed as 5.00. As shown in the tables, self-reported skills on these scales reflect substantial variation among the student population, though the data tops out at the high end of the scale. Nonetheless, sufficient variation appears to exist such that one can still discriminate among performance levels for different groups.

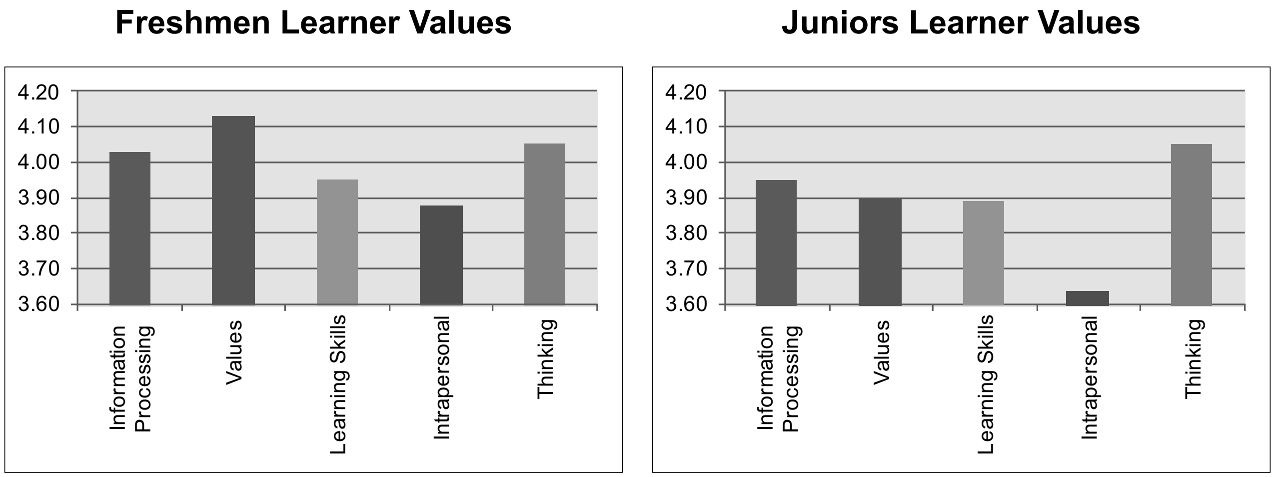
Student Self-Perceptions

We now look more deeply at how students rate their abilities. We consider the characteristics of each attribute on which freshman and junior-level students tend to rate themselves as particularly high or particularly low, and we compare general trends in the data with similar data from other studies.

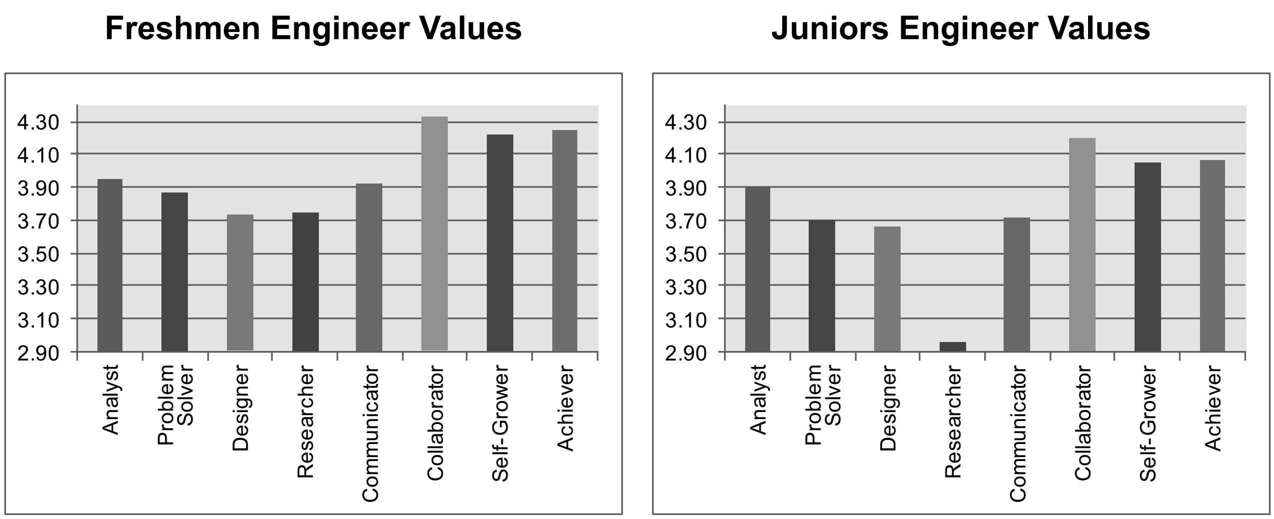
Profile of a Quality Learner

Overall, the students gave themselves very high ratings in all skills. For the learner categories, Figures 1 and 2, freshmen overwhelmingly self-reported score ranges between 3.8 and 4.2, while juniors reported slightly lower scores between 3.6 and 4.1. That said, there were some marked differences in how freshmen scored themselves compared to the juniors. Most distinctly, the freshmen scored themselves noticeably higher in almost all skill

Figures 1 & 2 Average self-reported learner ratings for each attribute by year



Figures 3 & 4 Average self-reported engineer rating for each attribute by year



sets; however both groups scored themselves equally highly as thinkers. Juniors also scored themselves noticeably lower on both the intrapersonal skill set and the values skill set, while they indicated a more marginal difference for information processing and learning skills.

Similarly, for the engineer categories, in Figures 3 and 4, on average students gave themselves high ratings for each attribute. The freshmen overwhelmingly favored score ranges between 3.7 and 4.4, and the juniors favored score ranges between 2.9 and 4.2. In contrast to the scores in the learner categories, between the freshmen and the junior scores, every skill in the engineer category saw a general scoring trend change. The juniors scored themselves marginally lower than the freshmen in all skill sets. And while both groups marked the collaborator skill with their highest scores for any skill set, the juniors marked the researcher skill set with their lowest scores for any skill set—quite noticeably lower than the freshmen had marked that same skill.

As a general rule, one might expect engineers to rate themselves highly for all of these measures. Based on the psychological study on professional engineers done by Ross Harrison, Winslow Hunt, and Theodore Jackson in 1955, engineers score higher than the general population on the Wonderlic general aptitude test (aptitude for learning and problem solving), and on tests measuring vocabulary, abstract reasoning, arithmetic reasoning, mechanical comprehension, and space relations. On each test, it is rare for the engineering group to fall below 10% of the mean scoring range of the general population. The mechanical comprehension test even measured freshmen engineering students compared with both professional engineers and the general population, finding the freshmen mean score to be higher than that

Pathways to Scholarly Teaching

<table>
<tr>
<th>Entry Point Model
(Utschig, 2012, unpublished)</th>
<th>Scaled Model
(Borrego, Streveler, Miller, Smith, Journal of Engineering Education, 2008)</th>
<th>Literary Genre Model
(Weimer, Enhancing Scholarly Work on Teaching & Learning, Jossey-Bass, 2006)</th>
</tr>
<tr>
<td>Reflective
(personal level)
Mechanisms for sharing ideas
Teaching Philosophy
Blogs
Books
Wikis</td>
<td>Excellent Teaching
Uses good content and teaching methods</td>
<td rowspan="2">Wisdom of Practice
Personal accounts of change
Self-driven change
Influence from others
Recommended Practices
Literature based
Experience based
Recommended Content
Literature based
Experience based
Personal Narratives
Personal approach
Emotional sometimes
Often advocates a position</td>
</tr>
<tr>
<td>Assessment Based
(personal or department level)
Mechanisms for sharing ideas
Course data
Program data
Accreditation</td>
<td>Scholarly Teaching
Based on best practices
Good content
Classroom assessment
Invites collaboration or review</td>
</tr>
<tr>
<td>Action Research
(discipline level or general learning, maybe $)
Mechanisms for sharing ideas
Conference presentation
Journal article
Within dept/institution
Web publishing</td>
<td>Scholarship of Teaching
Involves inquiry and investigation, particularly about student learning
Open to critique and evaluation</td>
<td rowspan="2">Research
Quantitative Investigations
Experimental design
Variable manipulation
Qualitative Studies
Interpretive analysis
often within natural setting for learning
Descriptive Research
Mostly survey based
Often looks at attitudes and perceptions</td>
</tr>
<tr>
<td>Educational Research
(pedagogical content knowledge level, discipline and/or general learning level, $ likely)
Mechanisms for sharing ideas
Conference presentation
Journal article
Funded grant work</td>
<td>Rigorous Research in Engineering Education
Addresses “how” and “why” questions about student learning
Broad dissemination</td>
</tr>
</table>

Writing Measurable Learning Outcomes

Criteria for Quality Outcome Statements [1,2]

- Define the *purpose* of the course for you and your students
- Have *action words* that describe what the student will KNOW and be able to DO differently as a result of your course
- Describe *meaningful* learning
- Are *measurable* - you can observe and measure students' ability to achieve them
- Represent a *high level* of learning, rather than trivial tasks
- Are written in *clear* language students can understand

Types of Outcomes [2,3]

Competency – what can someone do at the end of the course and at what level?

Movement or Growth – how much improvement is expected in a particular skill?

Accomplishment – what resume worthy result will come from the course?

Experience – what happened with enough emotional impact to cause serious reflection?

Integrated performance – how have students combined many forms of knowledge and skills in a professional performance without direct guidance or assistance?

Example Outcomes [1,2,3,4]

- (Competency) Demonstrate the addition of sine waves using physical devices, instrumentation, and graphs.
- (Competency) Use physical and chemical properties to determine the quality of paper samples and make recommendations based on specific requirements.
- (Movement) Improve assessment skills and process usage by elevating at least one level on the rubric "Assessor Performance".
- (Accomplishment) You will produce and document a major system incorporating at least 10 processes, 2-3 inputs, and 6 reports; addresses a real client's needs; meets industry specifications for quality; and includes a design manual and user manual.
- (Experience) Upon completing this course you will have reflected seriously upon the emotional impact of planning and interpreting formal discussions about contemporary and technically complex nuclear issues with the general public.
- (Integrated performance) Contrasts the theories presented in this course to explain why the motivation to become president is different for each of the primary candidates.

1. http://www.league.org/gettingresults/web/module2/learning/index.html, accessed 2012
2. Curriculum Design Handbook, Daniel K. Apple and Karl Krumsieg– Pacific Crest, 2003
3. *Faculty Guidebook: A Comprehensive Tool for Improving Faculty Performance,* 4th ed., Steven W. Beyerlein, Carol Holmes, Daniel K. Apple eds., Pacific Crest, 2007
4. Utschig – Introduction to Nuclear Engineering, Course Planning Notes, Georgia Institute of Technology, 2007

Example Outcomes – Thinking critically about criteria for quality [1]

Consider the following outcome statements. Based on what you've just read, which of the following meet the criteria listed above, and which need to be revised or totally rewritten? Compare your answers to those offered on the next page.

1. Understand Newton's three laws of motion. (competency)

2. Express numbers in scientific notation using the correct number of significant digits. (competency)

3. Diagnose failures in the vacuum, mechanical components, and controls of HVAC systems and determine necessary action for repairs. (competency or accomplishment)

4. Identify unknown bacteria using gram stain, biochemical, and other microbiological methods for identification. (competency)

5. Appreciate the difference between various forms of graphical representation. (competency)

1. http://www.league.org/gettingresults/web/module2/learning/index.html, accessed 2012

Example Outcomes – Improvements based on applying criteria [1]

1. "Understand" is not an action word and does not describe what students will be able to do differently as a result of the course.

   A better outcome might be: Use Newton's three laws of motion to predict motion in three dimensions.

2. This statement describes a discrete skill, but not an overarching goal of a class.

   A better outcome might be: Express and manipulate numbers effectively using the concepts of scientific notation, significant digits, and SI unit measurements.

3. This statement meets all the criteria.

4. This statement meets all the criteria.

5. This statement is vague and is not measurable.

   A better outcome might be: Given a set of data, construct a time series, scatterplot, or histogram to show relationships between quantities.

1. http://www.league.org/gettingresults/web/module2/learning/index.html, accessed 2012

Methodology for Writing Learning Outcomes:

1. Inventory content and context for learning
   a. Identify critical concepts, tools, skills, and behaviors that make up the course

   b. Identify difficult but important performance challenges for the learners

2. Rank the most important 3-5 items arising from the list above
3. Categorize each item as an outcome type
4. Draft outcomes - On successful completion of the course, you will be able to …
   1.

   2.

   3.

5. Revise outcomes to more fully incorporate relevant context (think of performance situations where the learners utilize the knowledge and skills identified in the outcome)
6. Revise outcomes to utilize blooms taxonomy and associated action verbs
7. Review to ensure criteria for quality outcomes are met