Assessment: Key to Improved STEM Learning by Undergraduates

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Why / What goals for higher ed?

- More graduates?
- Better graduates?
- What does better mean?
- More efficient resource allocation?
- Better alignment with HS graduates?
- Social goals – reducing under-representation?

Sources of pressure

- Quality of learning and student achievement
- Boyer Commission Report: Reinventing UG Ed
- Integration of research and education at NSF
- Nascent efforts: The Reinvention Center, Project Kaleidoscope
- Concerns about K-12 began to spill over to lower division higher education

Assessment Overview

- Increase in assessment interest
- Political / governmental pressure
- Institutional measures, pros and cons
- Course / student measures, pros and cons
- Student self report methods
- Influence on course design and instructional methods
- Critical Thinking / problem solving

NSF 2nd Review Criteria served by:

NSF Vision: "Effective integration of research and education at all levels infuses learning with the excitement of discovery and assures that the findings and methods of research are quickly and effectively communicated in a broader context and to a larger audience."

The larger audience is often interpreted as undergraduate students.

Other developments

- DUE / CCLI parallel track -> Educational quality can be improved substantially
- Angelo & Cross on classroom assessment
- ABET -> Engineering curriculum is too content focused, a spectrum of skills also needed
- Policy makers are beginning to understand this; engineering may be canary in the mine

Lisa Lattuca, Patrick Terenzini, & J Volkwein, *Engineering Change: Findings from a Study of the Impact of EC2000, Final Report*, ABET, 2006

Carryover from K-12: "standards"

- Easier to specify at the institutional level in broad terms
- However, they are only a starting point
- Let us consider this for a moment

Institutional Assessment: Basic Metrics

- Graduation rates (influenced by many things)
- Persistence rates (many measures, but perhaps a better longitudinal measure)
- NSSE Survey scores (comparison vs. longitudinal improvement)
- Institution wide assessment; examples
  - Math and science skills (Donna Sundre, .. JMU)
  - Critical thinking skills (Barry Stein, Ada Haynes, ..)

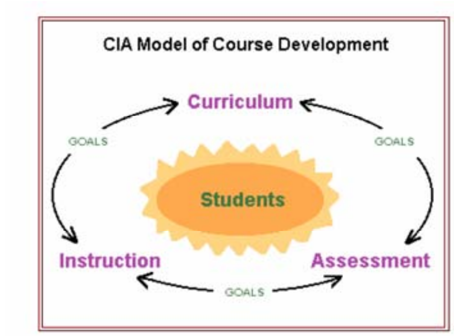
Moving focus from institution to course

Some in-between methods; adopting good practices

- Classroom observation (e.g. RTOP for reform teaching)
- Deliberate blending of F2F and online course structures, building in assessment via online ->

P-S Chen, K Guidry, & A Lambert, *Engaging online learners: A quantitative study of postsecondary student engagement in the online learning environment* (AERA, 2009)

A Generalized Model for Course Development (FLAG)



Field-tested Learning Assessment Guides:

"There is considerable evidence showing that **assessment drives student learning**. More than anything else, our assessment tools tell students what we consider to be important. They will learn what we guide them to learn through our assessments. Traditional testing methods have been limited measures of student learning, and equally important, of limited value for guiding student learning. These methods are often inconsistent with the increasing emphasis being placed on the ability of students to develop higher order thinking skills."

The NSF Division of Undergraduate Ed (DUE)

DUE believes that all students need to grasp science and math at a basic functional level. We have focused as much on courses for non-STEM majors as on STEM majors.

DUE has had a particular concern for pre-service teachers, especially elementary pre-service teachers.

Explicit & Implicit DUE / CCLI Assessment Goals

- Assessing student interest and "affect"
- Identifying the key concepts of science for non-majors and fledgling experts
- Finding the difficult key concepts - where learning is confounded by "misconceptions."
- Ensuring that the pace of intro classes is well matched to student learning
- Higher order thinking skills; transformation
- Improved long-term retention

Student meta-cognition and self-assessment

Brand new web site known as the

SALGsite: Student assessment of their (own) learning gains.

A formative instrument for use in monitoring student progress.

Also, an instrument for measuring pre and post understanding in curriculum design

Focus of rest of this keynote talk

- Illustrate some assessment methods, a few general and a few specific
  - Many of these employ assessment instruments specific to the discipline
  - Some use research on student misconceptions
- Provide some illustrations of putting the FLAG assessment mantra to work in recent DUE grants

Getting Started with discipline-based assessment

- Concept inventories – are specific to disciplines
- They use MC tests to ease scoring and challenge student knowledge with "distracters" (ALL answer choices play a role in the test)
  - The GeoScience CI: Julie Libarkin and Steve Anderson; a significant leap forward
  - Comp assess outcomes for a 1rst course in stats (CAOS), Joan Garfield, Beth Chance, R Delmas
  - Hierarchical Biology Concept Framework: a tool for course design (BCF)

GeoScience CI Examples

- Students confuse gravity and magnetic force
- Many students believe sound is a form of wind
- Think about how you would tackle this mis-conceptions head-on…

Statistics example: CAOS

- Has good psychometric properties; tested across 39 first stats courses at 33 instns
- Use of *p*-values (statistical measures of significance) gives students difficulty; one source notes at least 13 different misconceptions about *p*-values; people struggle with the logic of inference.
- For example, >50% believed a high *p*-value means that data are statistically significant.

CAOS Q : are people less likely to have a fatal accident with a seatbelt? Here are 3 choices:
Compare 510 to 1,601
Compare 510/412K to 1,601/164K
Compare 510/577K to 1601/577K

Safety Equipment in Use	Injury		ROW TOTAL
	Nonfatal	Fatal	
Seat Belt	412,368	510	412,878
No Seat Belt	162,527	1,601	164,128
COLUMN TOTAL	574,895	2,111	577,006

Biology Concept Framework (BCF)

- 1. Biology is based on observational and experimental science.
- 2. At the molecular level, biology is based on three-dimensional interactions of complementary surfaces.
- 3. The cell is the basic unit of life.
- 4. All cells share many processes/mechanisms.
- 5. Cells interact with other cells.
- 6. Cells are created from other cells.

Biology Concept Framework (BCF) - 2

- 7. DNA is the source of heritable information in a cell.
- 8. A gene is the functional unit of heredity.
- 9. The structure of DNA dictates the mechanism of the production of nucleic acids and proteins.
- 10. Sexual reproduction is a powerful source of variation.
- 11. Life processes are the result of regulated chemical reactions.
- 12. Proteins perform many varied functions in a cell.

Biology Concept Framework (BCF) - 3

- 13. Recombinant DNA technology allows scientists to manipulate the genetic composition of a cell.
- 14. The expression of genes is regulated.
- 15. All carbon-containing biomass is created from CO_2.
- 16. Populations of organisms evolve because of variation and selection.
- 17. Organisms and the environment modify each other.
- 18. In multicellular organisms, multiple cell types can work together to form tissues which work together to form organs.

Testing Student Values in science / math

"Assessing **Students Value for Science and Math Literacy**," Mark Wood et al (Drury) in *Proceedings … 2006.*

- Two inventories, one in math and one in science:

<u>Sample questions in math:</u>

- **Interest**: Solving math problems is interesting for me.
- **General Utility**: I see no point in being able to do math; I have little to gain by learning how to do math
- **Need for Achievement**: Doing well in math courses is important to me.
- **Costs**: Math exams scare me.

Testing Student Values in science / math

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<u>Sample questions in science:</u>

- **Conflict with Religiosity**: Learning science undermines my religious beliefs;
- I must hide my religious faith when taking courses in science.

Eric Mazur's Work

- See Eric Mazur, *Peer Instruction, A User's Manual,* Prentice Hall, 1997
- Use of ConcepTests
- Peer to peer discussions

Ron Stevens & Melanie Cooper's work

Melanie Cooper, Ron Stevens, and Thomas Hulme, "Assessing problem solving strategies in Chemistry using the IMMEX System," *Proceedings of the National STEM assessment conference, Oct 2006 (*Drury University, 2007)

Long-term knowledge retention

- Karpicke's work (Purdue Univ, Dept of Psych), award 0941170: "Retrieval Practice"
- Roediger & Karpicke, "Test Enhanced Learning," Psychological Science, 2006.
- Daniel Klionsky, "The Quiz Factor, *Letter to the editor,* CBE-Life Sciences Education, 2008.
- Mark McDaniel, et al, *Testing the testing effect in the classroom,* European Journal of Cognitive Psychology, 2007.

Some recent NSF grants

- Sacha Kopp, U of Texas, Award 0942943

$CO_2 + H_2O + \text{sunlight energy} \rightarrow C_6H_{12}O_6 + O_2$

carbon dioxide, water, glucose, oxygen

39 Which molecule in the equation represents food energy made by plants?

A Carbon dioxide

B Water

C Glucose

D Oxygen

Some recent NSF grants

- Mary Jane Rice, Michigan State U, Award 0941820.

Uses material from:

- Rice and Neureither, *An Integrated Physical, Earth, and Life Science Course of Pre-Service K-8 Teachers,* Journal of Geoscience Education, 2006

Content Focus of Rice’s Work

- Matter changes physically and chemically, yet is conserved
- Energy changes in transfers and transformations, yet is conserved
- When matter changes, energy’s involved

An Integrative View in Biology

Katayoun Chamany, Deborah Allen, and Kimberly Tanner, "Making Biology Learning Relevant to Students: Integrating People, History, and Context into College Biology Teaching," CBE-Life Sciences (2008).

Allchin, "How *Not* to Teach History of Science," 2000.

Contextually rich STEM teaching

- **Case Studies in Science (book).** Herreid, C. F. (2007). Start with A Story. The Case Method of Teaching College Science, Arlington, VA: NSTA Press. *Collection of articles and strategies for teaching with case studies.*

Contextually rich STEM: ONLINE materials

- National Center for Case Study Teaching in Science. C. F. Herreid and N. Schiller, Directors, State University of New York at Buffalo Case Collection. http://ublib.buffalo.edu/libraries/projects/cases/case.html (accessed 12 October 2009). *Clearinghouse for case studies organized by discipline and author; teaching notes, assignments, and password-protected answer keys provided.*

Contextually rich STEM: ONLINE materials

- University of Delaware. Problem-Based Learning Clearinghouse. www.mis4.udel.edu/Pbl/index.jsp (accessed 8 March 2008). *Clearinghouse for problems in social context.*
- Science Education for New Civic Engagements and Responsibilities (online). www.sencer.net (accessed 12 October 2009). *Collection of model course curricula; other information.*