STEM Education Classrooms

Promising Practices
for
Improved Learning

2012 ASQ STEM Agenda Conference

Advancing the STEM Agenda in Education, the Workplace and Society

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PROMISING PRACTICES

CURRENT STATE OF STEM EDUCATION

What are evidence-supported promising practices in STEM education?

1. Writing Course Learning Outcomes
2. Students Learning in Small Groups
3. Students Organized in Learning Communities
4. Scenario-based Content Organization
5. Feedback through Systematic Formative Assessment
6. Designing In-class Activities to Actively Engage Students
7. Undergraduate Research

How might promising practices be evaluated?

- Implementation Standards
  - Implementation standards characterize the extent to which faculty members must change to implement a promising practice.
  - How easily can faculty members implement?
- Student Performance Standards
  - Student performance standards characterize the extent to which research supports the efficacy (with respect to student learning) of a promising practice.
  - Is there evidence to support improved learning?

Promising Practices	Implementation Ratings	Student Performance Ratings
1. Writing Course Learning Outcomes	Strong	Good
2. Small Group Learning	Strong	Strong
3. Student Learning Communities	Fair	Fair to Good
4. Scenario-based Content Organization	Good to Strong	Good
5: Systematic Formative Feedback	Strong	Good
6: In-class Active Engagement Activities	Strong	Strong
7. Undergraduate Research	Strong or Fair	Fair

Resource

- Froyd, J. E. (2008). *White paper on promising practices in undergraduate STEM education*. Paper presented at the Workshop on Evidence on Promising Practices in Undergraduate Science, Technology, Engineering, and Mathematics (STEM) Education. Retrieved from http://www7.nationalacademies.org/bose/Froyd_Promising_Practices_CommissionedPaper.pdf

Questions?

Promising Practice No. 1
Writing Course Learning Outcomes

- Frequently mentioned desirable abilities for STEM graduates
  - Critical thinking
  - Self assessment (part of lifelong learning)
  - Integrative, interdisciplinary thinking
  - Creating/design
  - Systems thinking
  - …
- Challenge: Often these desirable abilities are only articulated in these poorly characterized terms

Promising Practice No. 1
Learning Outcomes

- Critical thinking
  - Susan Wolcott, http://www.wolcottlynch.com
- Self assessment
  - Alverno College, http://depts.alverno.edu/saal/selfassess.html
- Integrative, interdisciplinary thinking
  - (Boix Mansilla & Duraisingh, 2007)
- Creating/design
  - ?
- Systems thinking
  - ?

Boix Mansilla, V., and Duraisingh, E. D. (2007). Targeted Assessment of Students' Interdisciplinary Work: An Empirically Grounded Framework Proposed, *The Journal of Higher Education, 78*(2), 215–237

Promising Practice No. 2
Students Learning in Small Groups

- Jigsaw (http://www.jigsaw.org)
- Paired Problem Solving
- Collaborative Writing
- Structured Controversy
- Team Projects
- Process Oriented Guided Inquiry Learning (POGIL – Chemistry)
- Peer Led Team Learning (PLTL)
- …

Promising Practice No. 2
Students Learning in Small Groups

- Do your small group learning activities address all five of these elements?
  - – Positive Interdependence
  - – Individual Accountability
  - – Face-to-face Promotive Interaction
  - – Group Processing
  - – Social Skills Development

http://www.foundationcoalition.org/publications/brochures/acl_piiapi.pdf

Promising Practice No. 2
Students Learning in Small Groups

- Springer, L., Stanne, M. E., and Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. Review of Educational Research, 69(1), 21–51.
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- Bowen, C. W. (2000). A Quantitative Literature Review of Cooperative Learning Effects on High School and College Chemistry Achievement. Journal of Chemical Education, 77(1), 116–119
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- Bonsangue, M. (1994). An efficacy study of the calculus workshop model. CBMS Issues in Collegiate Mathematics Education, 4, Providence, RI: American Mathematical Society, 117–137
- Beichner, R. J., Saul, J. M., Abbott, D. S., Morse, J. J., Deardorff, D. L., Allain, R. J., Bonham, J. W., Dancy, M. H., and Risley, J. S. (2007). The Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP) Project. Retrieved August 27, 2007, from http://www.compadre.org/Repository/document/ServeFile.cfm?ID=4517&DocID=183
- Tien, L. T., Roth, V., and Kampmeier, J. A. (2001). Implementation of a Peer-Led Team Learning Instructional Approach in an Undergraduate Organic Chemistry Course. Journal of Research in Science Teaching, 39(7), 606–632
- Born, W. K., Revelle, W., and Pinto, L. H. (2002). Improving Biology Performance with Workshop Groups. Journal of Science Education and Technology, 11(4), 347– 365

Promising Practice No. 3

Students Organized in Learning Communities

- Learning Communities: One or more structural (and pedagogical) mechanisms to help students relate and connect across multiple courses
  - Relate and connect concepts, ideas, skills, techniques…
  - Relate and connect socially
- "In higher education, curricular learning communities are classes that are linked or clustered during an academic term, often around an interdisciplinary theme, and enroll a common cohort of students. A variety of approaches are used to build these learning communities, with all intended to restructure the students' time, credit, and learning experiences to build community among students, between students and their teachers, and among faculty members and disciplines." (http://www.evergreen.edu/washcenter/lcfaq.htm)

Promising Practice No. 3

Students Organized in Learning Communities

- Froyd, J., and Ohland, M. (2005). Integrated Engineering Curricula, *Journal of Engineering Education, 94*(1), 147–164.
- Smith, B. L., J. MacGregor, R. Matthews, and F. Gabelnick. 2004. *Learning Communities: Reforming Undergraduate Education*. San Francisco, CA: Jossey-Bass.

Promising Practice No. 4
Scenario-based Content Organization

- Organize content around carefully posed scenarios, questions, challenges, problems, projects…
  - Problem Based Learning
  - Inquiry Based Learning
  - Challenge Based Learning
  - Project Based Learning
  - Undergraduate Research
  - Guided Inquiry Learning
  - Question Driven Instruction

Promising Practice No. 4
Scenario-based Content Organization

- Real Challenge
  - How do you facilitate multiple groups of learners engaging your posed challenges?
- Scenarios differ in:
  - Length of activity
  - Support offered during activity (Kirschner, Sweller, & Clark, 2006; Mayer, 2004)
  - Guidelines for developing scenarios

Cordray, D. S., Pion, G. M., Harris, A., & Norris, P. (2003). The value of the VaNTH Engineering Research Center: Assessing and evaluating the effects of educational innovations on large educational research projects in bioengineering. *IEEE Engineering in Medicine and Biology Magazine, 22*, 47–54.

Beatty, I. D., Leonard, W. J., Gerace, W. J., Dufresne (2006). Question Driven Instruction: Teaching Science (Well) with an Audience Response System. In Banks, D. A. (ed.) *Audience Response Systems in Higher Education: Applications and Cases*, Hershey, PA: Information Science Publishing.

Kirschner, P. A., Sweller, J, and Clark, R. E. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. Educational Psychologist, 41(2), 75–86.

Mayer, R. E. (2004). Should There Be a Three-Strikes Rule Against Pure Discovery Learning? The Case for Guided Methods of Instruction. *American Psychologist, 59*(1), 14–19.

Promising Practice No. 4

Scenario-based Content Organization

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- Prince, M., and Felder, R. (2007). The Many Faces of Inductive Teaching and Learning. *Journal of College Science Teaching, 36*(5), 14–20
- Dochy, F., Segers M., Van den Bossche, P., and Gijbels, D. (2003). Effects of Problem-Based Learning: A Meta-Analysis. *Learning and Instruction, 13*, 533–568
- Gijbels, D., Dochy, F., Van den Bossche, P., and Segers, M. (2005). Effects of Problem-Based Learning: A Meta-Analysis from the Angle of Assessment. *Review of Educational Research, 75*(1), 27–61
- Vernon, D. T. A., and Blake, R. L. (1993). Does Problem-Based Learning Work? A Meta-Analysis of Evaluative Research. *Academic Medicine, 68*, 550–563.
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- Farrell, J. J., Moog, R. S., and Spencer, J. N. (1999). A Guided Inquiry General Chemistry Course. *Journal of Chemical Education, 74*(4), 570–574
- Lewis, S. E., and Lewis, J. E. (2005). Departing from Lectures: An Evaluation of a Peer-Led Guided Inquiry Alternative. *Journal of Chemical Education, 82*(1), 135–139
- Roselli, R. J., and Brophy, S. P. (2006). Effectiveness of Challenge-Based Instruction in Biomechanics. *Journal of Engineering Education, 95*(4), 311–324.

Promising Practice No. 5

Feedback through Systematic Formative Assessment

- Design a systematic plan for formative assessment activities primarily for the purpose of providing feedback to students about their learning

Promising Practice No. 5

Feedback through Systematic Formative Assessment

- "A recent review (Black and William, 1998) revealed that classroom-based formative assessment, when appropriately used, can positively affect learning.....students learn more when they receive feedback about particular qualities of their work, along with advice on what they can do to improve" (National Research Council, 2001)

- National Research Council (2001). *Knowing What Students Know: The Science and Design of Educational Assessment.* Washington, DC: National Academies Press.
- Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education: Principles, Policy & Practice, 5*(1), 7–74.

Promising Practice No. 5

Feedback through Systematic Formative Assessment

- Approaches for formative feedback
  - Classroom assessment techniques (Angelo & Cross, 1993)
    - Minute Paper (Stead, 2006)
  - Classroom response systems
    - Summary (Fies & Marshall, 2006)
    - Peer Instruction (Mazar, 1997; Crouch & Mazur, 2001)

- Angelo, T. A., & Cross, P. K. (1993). *Classroom Assessment Techniques: A Handbook for College Teachers* (Second ed.). San Francisco, CA: Jossey-Bass.
- Stead, D. R. (2005). A review of the one-minute paper. *Active Learning in Higher Education, 6(*2), 118–131.
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- Mazur, E. (1997). *Peer Instruction: A User's Manual*. Upper Saddle River, NJ: Prentice Hall
- Crouch, C.H., and Mazur, E. (2001). Peer Instruction: Ten years of experience and results. *American Journal of Physics, 69*(9), 970–977

Promising Practice No. 6

Designing In-class Activities to Actively Engage Students

- Think – Pair – Share (Lyman, 1981)
- Bookend Lectures (Smith et al., 2005)
- ConcepTests
- Just-in-time Teaching (Novak, 1998)
- Peer Instruction (Mazur, 1997)
- …

Promising Practice No. 6

Designing In-class Activities to Actively Engage Students

- Crouch, C.H., and Mazur, E. (2001). Peer Instruction: Ten years of experience and results. *American Journal of Physics, 69*(9), 970–977.
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- Redish, E. F., Saul, J. M., and Steinberg, R. N. (1997). On the effectiveness of active-engagement microcomputer-based laboratories. *American Journal of Physics, 65*(1), 45–54.
- Cummings, K., Marx, J., Thornton, R., and Kuhl, D. (1999). Evaluating innovations in studio physics. *American Journal of Physics, 67*(supplement 1 to no. 7), S38–S44.
- Hoellwarth, C., Moelter, M. J., and Knight, R. D. (2005). A direct comparison of conceptual learning and problem solving ability in traditional and studio style classrooms. *American Journal of Physics, 73*(5), 459–462.
- Michael, J. (2006). Where's the evidence that active learning works? *Advances in Physiology Education, 30*, 159–167.
- Knight, J. K., and Wood, W. B. (2005). Teaching More by Lecturing Less. *Cell Biology Education, 4*, 298–310.
- Freeman, S., O'Connor, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., Dirks, C., and Wenderoth, M. P., (2007). Prescribed Active Learning Increases Performance in Introductory Biology. *Cell Biology Education, 6*, 132–139.

Promising Practice No. 7

Undergraduate Research

- Undergraduate research
  - Implementation Criteria
    - Significant resources to support one-to-one relationships, other models may offer opportunities for greater student participation
  - Student Performance Criteria
    - Some implementation studies, no known comparison studies
    - Supported via literature on the value student engagement with faculty

Promising Practice No. 7

Undergraduate Research

- Seymour, E., Hunter, A.-B., Laursen, S. L., and Diatonic, T. (2004). Establishing the Benefits of Research Experiences for Undergraduates in the Sciences: First Findings from a Three-Year Study. *Science Education, 88*, 493–534.
- Lopatto, D. (2004). Survey of Undergraduate Research Experiences (SURE): First Findings. *Cell Biology Education, 3*, 270–277..
- Hunter, A.-B., Laursen, S. L., and Seymour, E. (2007). Becoming a Scientist: The Role of Undergraduate Research in Students' Cognitive, Personal, and Professional Development. *Science Education, 91*, 36–74.
- Russell, S. H., Hancock, M. P., and McCullough, J. (2007). Benefits of Undergraduate Research Experiences. *Science, 316*, 548–549.

Questions?

FUTURE DIRECTIONS IN UNDERGRADUATE STEM EDUCATION

Starting Point: In thinking about the objectives of part 2, I thought it important to digress into a brief conversation about means and ends.

Means – How are the ends is trying to be achieved?

Ends – What is trying to be achieved?

Next, I thought a brief conversation educational ends might be appropriate.

How might educational ends (or goals) be classified?

Content: Students have to know about…

- Mechanical engineering
- Chemistry
- History
- Genetics
- Finance
- …

Process: Students have to know how to…

- Critical thinking
- Systems thinking
- Design
- Communicate
  - In writing
  - To large groups
  - Within small groups
- …

Coppola, B. P., & Daniels, D. S. (1996). Structuring the Liberal (Arts) Education in Chemistry. *The Chemical Educator, 1*(2), 1-32

How might process educational goals be clarified?

- Open-ended problem solving
- Ethical reasoning
- Innovation reasoning
- Qualitative reasoning
- Quantitative reasoning
- Critical reasoning
- Creative reasoning
- Systems reasoning
- Computational reasoning
- Leading and working effectively within interdisciplinary teams
- Metacognitive/reflective thinking
- Design
- Communicate
  - In writing
  - To large groups
  - Within small groups
- …

How well do faculty members understanding process educational goals?

- How many course titles in higher education reflect process educational goals?
- Alan Schoenfeld, Mathematics, University of California Berkeley, theorem proving
- Don Woods, Chemical Engineering, McMasters University, problem solving
- …

"Despite individual professors' dedication and efforts to develop problem solving skill, "general problem solving skill" was not developed in the four years in our undergraduate program. **Students graduated showing the same inability that they had when they started the program.** Some could not create hypotheses; some misread problem statements. During the four-year undergraduate engineering program studied, 1974-1978, the students had worked over 3000 homework problems, they had observed about 1000 sample solutions being worked on the board by either the teacher or by peers, and they had worked many open-ended problems. In other words, they showed no improvement in problem solving skills despite the best intentions of their instructors."

Woods, D. R., Hrymak, A. N., Marshall, R. R., Wood, P. E., Hoffman, T. W., Wright, J. D., et al. (1997). Developing problem solving skills: The McMaster Problem Solving Program. *Journal of Engineering Education, 86*(2), 75-92.

Not my students!

How do you think about content and process?

Process ⟷ Content

Coppola and Daniels encourage readers to discard notions of tradeoffs between process and content?

X No! X

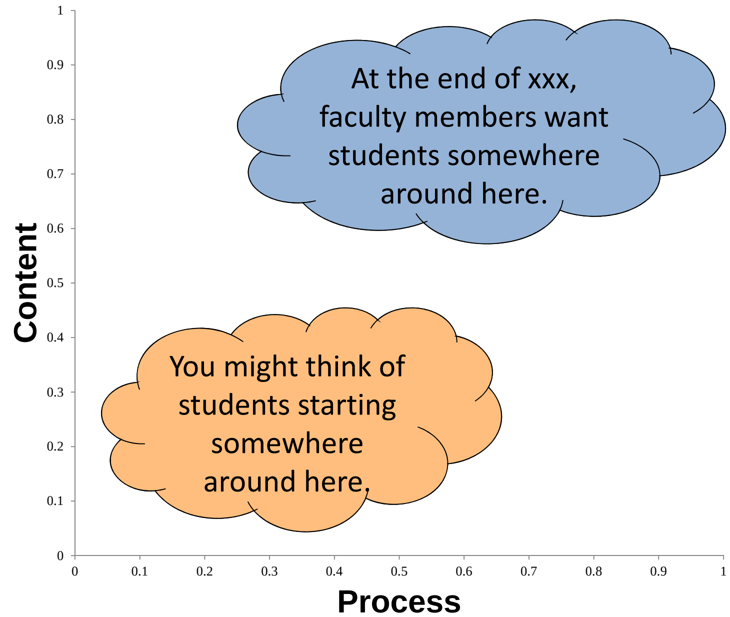
Coppola and Daniels encourage readers to discard notions of tradeoffs between process and content?

	Process	
Content	(High Content, Low Process)	(High Content, High Process)
	(Low Content, Low Process)	(Low Content, High Process)

Coppola, B. P., & Daniels, D. S. (1996). Structuring the Liberal (Arts) Education in Chemistry. *The Chemical Educator, 1*(2), 1-32

	Process	
Content	(High Content, Low Process) ?	(High Content, High Process) Experts
	(Low Content, Low Process) Unengaged	(Low Content, High Process) ?

Coppola, B. P., & Daniels, D. S. (1996). Structuring the Liberal (Arts) Education in Chemistry. *The Chemical Educator, 1*(2), 1-32



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	Process	
Content	(High Content, Low Process) Encyclopedists	(High Content, High Process) Experts
	(Low Content, Low Process) Unengaged	(Low Content, High Process) Intellectual Amnesiacs

Coppola, B. P., & Daniels, D. S. (1996). Structuring the Liberal (Arts) Education in Chemistry. *The Chemical Educator, 1*(2), 1-32

What can we talk about within this framework?

- Contrast development
- Paths to expert quadrant

Content Development

vs.

Process Development

What are characteristics of content development?

- Knowledge delivery
  - Facts
  - Procedures
  - Civil Engineering: Body of Knowledge
- Knowledge organization (on the part of learners)
  - Concept maps
  - Novice vs. expert
- Delivery and assessment are aligned (to some degree) with mass media capabilities

What are characteristics of process development?

- Deliberate practice (Ericsson & Krampe)
  - Practice + feedback
  - Reflection / metacognitive development
  - 10,000 hours for world-class expertise
- Heuristics
  - Writing:
  - Problem solving (Polya):

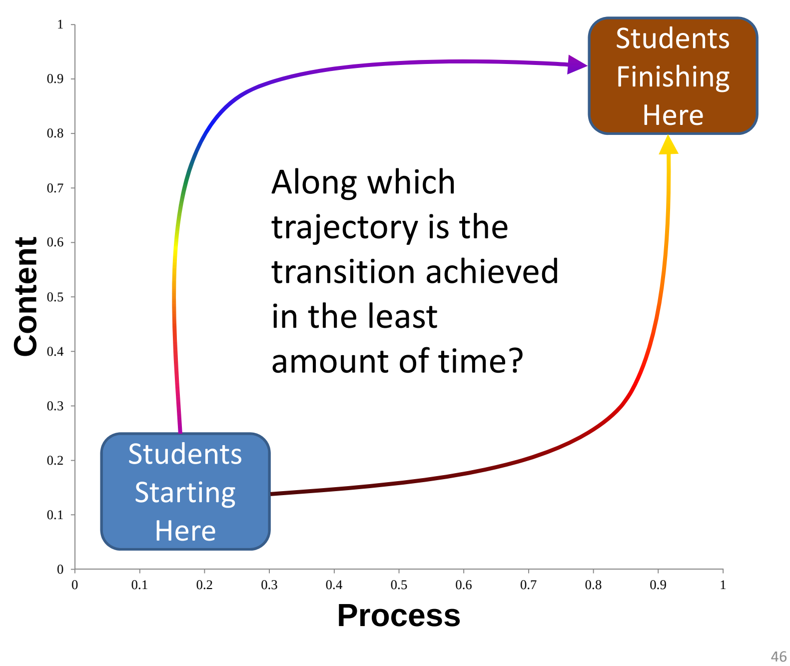
Ericsson, K. A., & Krampe, R. T. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363-406.

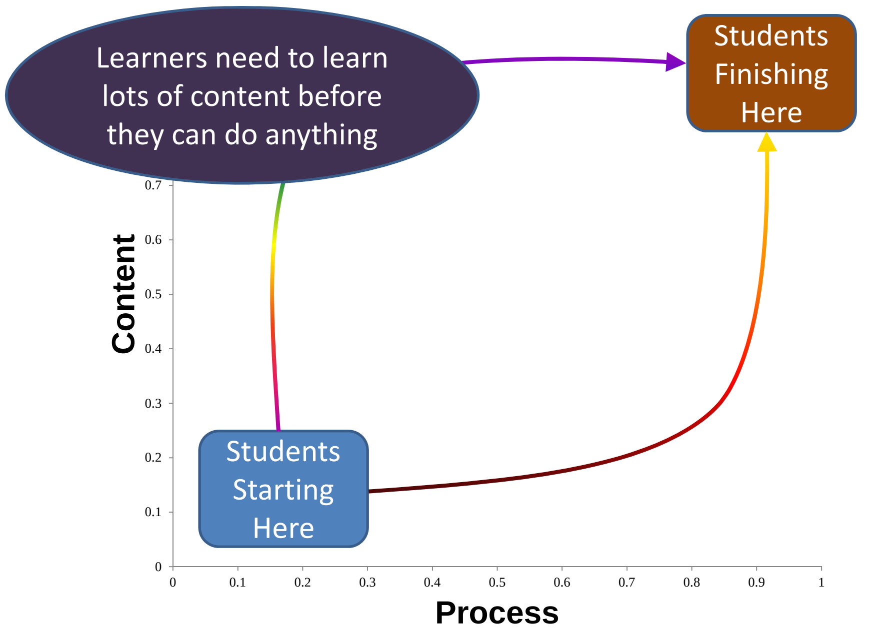
What are characteristics of process development?

- **Assessment**
  - Time intensive
  - Context intensive
  - Expertise intensive
- **Delivery and assessment are not well aligned with mass media capabilities**

Questions?

Exploring Paths to the Expert Quadrant





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	Innovation	
Efficiency	(High Efficiency, Low Innovation) Routine Expert	(High Efficiency, High Innovation) Adaptive Expert
	(Low Efficiency, Low Innovation) Novice	(Low Efficiency, High Innovation) ?

Schwartz, D. L., Bransford, J. D., & Sears, D. (2005). Efficiency and Innovation in Transfer. In *Transfer of Learning from a Modern Multidisciplinary Perspective*, J. Mestre (Ed.) Greenwich, CT: Information Age Publishing, 1-51

	Innovation	
Efficiency	(High Efficiency, Low Innovation) Routine Expert	(High Efficiency, High Innovation) Adaptive Expert
	(Low Efficiency, Low Innovation) Novice	(Low Efficiency, High Innovation) Intelligent Novices (Bruer)

Schwartz, D. L., Bransford, J. D., & Sears, D. (2005). Efficiency and Innovation in Transfer. In *Transfer of Learning from a Modern Multidisciplinary Perspective*, J. Mestre (Ed.) Greenwich, CT: Information Age Publishing, 1-51

Within the innovation-efficiency framework, I would like to describe an experiment whose results can be interpreted as a very preliminary test of two different paths from novice to adaptive expertise.

Schwartz, D. L., & Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction, 22*(2), 129-184.

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- **Tell-and-practice Set (Content Emphasis First)**
  - Teacher talked about grading on a curve and gave students a procedure for marking deviation regions on a histogram to compare grades.
  - Students practiced on a new data set for comparing grades.

- **Invention Set (Process Emphasis First)**
  - Students (in small groups) tried to invent a way to determine whether a long jump or pole vault competitor had broken their sport's prior world record by a greater relative amount.
  - There were:
    - No class presentations
    - No sharing of solutions
    - No feedback to the students about their inventions.

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From the two sets, create four sets:

- Two subsets of the tell-and-practice-set and the invention set took a post-test with a worked example related to the subject of the post test

- Two other subsets took the post-test with no resource.

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	Invent Way to Determine Relative Performance of High Jumpers	
Received Worked Example on Post Test	(No invention, worked example) Undistinguished Performance	(Invention, worked example) Significantly better performance
	(No invention, no worked example) Undistinguished Performance	(Invention, no worked example) Undistinguished Performance

Coppola, B. P., & Daniels, D. S. (1996). Structuring the Liberal (Arts) Education in Chemistry. *The Chemical Educator, 1*(2), 1-32

"Of the four different [subsets] with results from the post-test, only one [subset] demonstrated significantly improved performance:

- The group that received the invention intervention and the worked example.
- That is, "the students who invented their own methods for standardizing data learned from a worked example embedded in the test and spontaneously transferred this learning to solve a novel problem, even more so than students who had been told and had practiced a specific visual technique for standardizing data"

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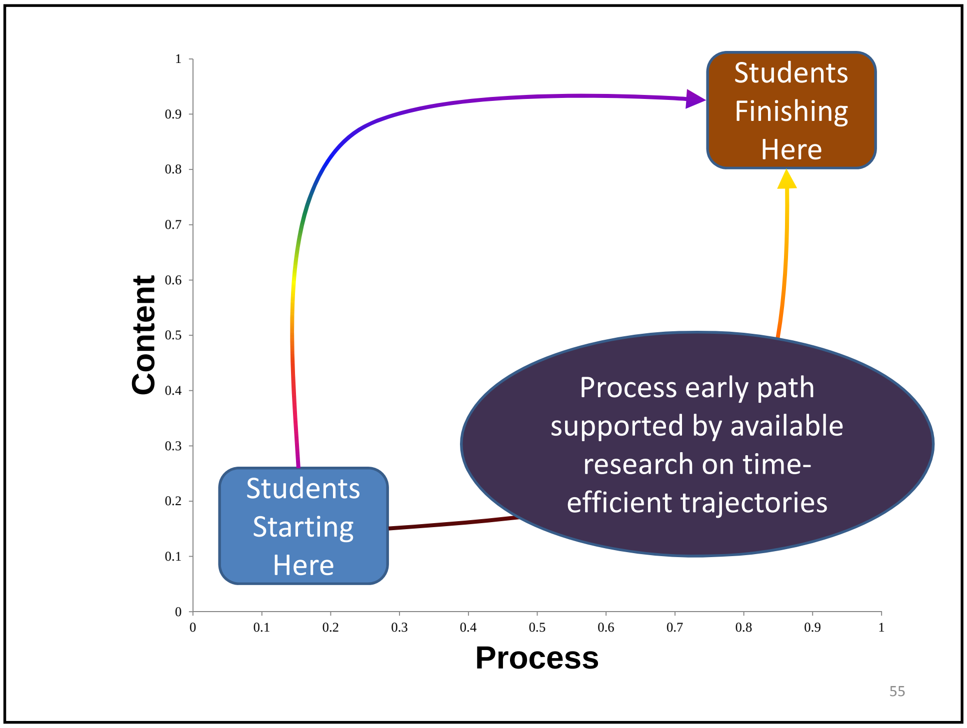


Conclusions

- Each of the seven promising practices can be implemented in courses you are currently teaching.
  - Examples are available for a wide variety of courses.
- Process-early trajectories appear to offer more time-efficient trajectories toward achieving experts/adaptive experts and are consistent with several promising practices:
  1. Writing Course Learning Outcomes
  2. Students Learning in Small Groups
  3. Scenario-based Content Organization / Undergraduate Research
  4. Feedback through Systematic Formative Assessment
  5. Designing In-class Activities to Actively Engage Students

Questions?

Active Learning: Does It Really Work in Science, Technology, Engineering and Mathematics Courses?

Nanyang Technological University
Annual Learning and Teaching Seminar:
From Good to Great 2012

Jeffrey E. Froyd
TEES Research Professor
Texas A&M University

Research-based Instruction Strategies (RBIS)

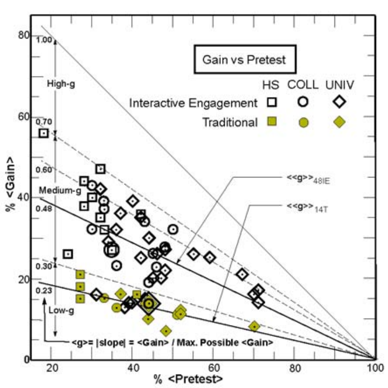
- Think – Pair – Share
- Active Learning
- Collaborative Learning
- Cooperative Learning
- ConcepTests
- Peer Instruction
- Problem-based Learning
- Project-based Learning
- Challenge-based Learning
- Inquiry-based Learning
  - Inquiry-guided learning
  - Process-based Guided-inquiry Learning (POGIL)
- Peer-led Team Learning (PLTL)
- …

Why RBIS?

- **Wright, J. C., Millar, S. B., Kosciuk, S. A., Penberthy, D. L., Williams, P. H., Wampold, B. E. (1998). [A Novel Strategy for Assessing the Effects of Curriculum Reform on Student Competence](). *Journal of Chemical Education, 85*(8), 986-992**
  - Study shows a very thorough assessment of differences between a well-taught lecture class and a structured active learning class through the eyes of faculty who teach subsequent courses
  - Significant differences were observed in higher-order thinking

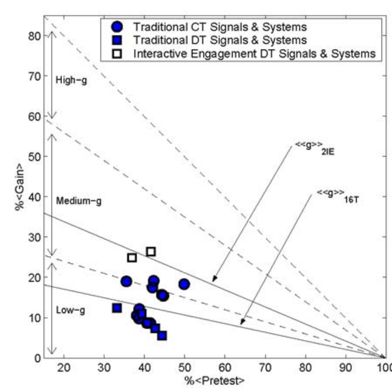
Comparison of Hake's FCI gain results to SSCI gain results

FCI



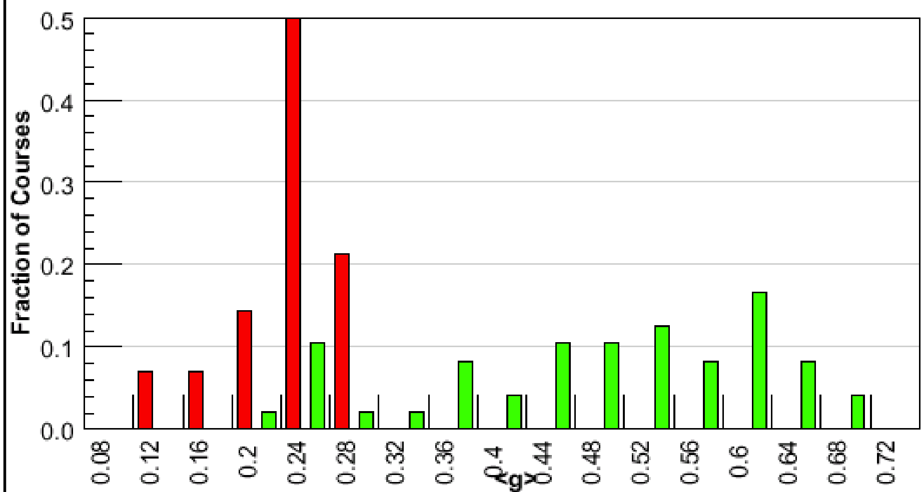
FCI gain results (Hake 1998)
Traditional avg gain = 0.23± 0.04
Interactive avg gain = 0.48±0.14

SSCI



SSCI v2.0 gain results (Wage/Buck)
Traditional avg gain = 0.21± 0.08
Interactive avg gain = 0.42± 0.04

Why Active/Cooperative Learning?



Hake, R. R., (1998). Interactive-engagement vs. traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, 66, 64- 74

Why RBIS?

Learning Outcome (collaborative vs. individualistic)	Effect Size	Reference
Improved academic achievement	0.64	Johnson, Johnson, & Smith (1998a)
Improved quality of interpersonal interactions	0.60	
Improved self-esteem	0.44	
Improved perceptions of greater social support	0.70	
Improved academic achievement	0.53	Johnson, Johnson, & Smith (1998b)
Improved quality of interpersonal interactions	0.55	
Improved self-esteem	0.29	
Improved perceptions of greater social support	0.51	

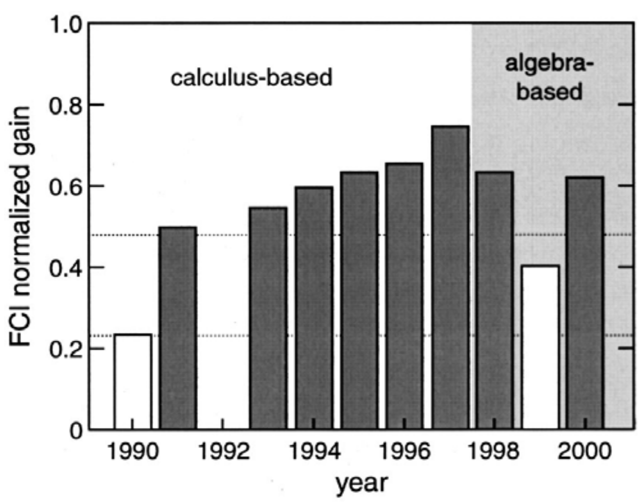
Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education, 93*(3), 223-231

Why RBIS?

Learning Outcome (collaborative vs. individualistic)	Effect Size	Reference
Improved academic achievement	0.51	Springer, Stanne, & Donovan (1999)
Improved student attitudes	0.55	
Improved retention in academic programs	0.46	

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education, 93*(3), 223-231

Why RBIS? Here results from a multi-year study of peer instruction in physics.



Average Force Concept Inventory normalized gain for introductory calculus-based physics, Harvard University, Fall 1990–Fall 1997, and for introductory algebra-based physics, Harvard University, Fall 1998–Fall 2000. Open bars indicate traditionally taught courses and filled bars indicate courses taught with PI [peer instruction]. Dotted lines correspond to <g> = 0.23, the typical gain for a traditionally taught course, and <g> = 0.48, the typical gain for an interactive course (Hake).

Crouch, C.H., and Mazur, E. (2001) Peer Instruction: Ten years of experience and results. *American Journal of Physics, 69*(9), 970-977

Why RBIS?

Course-related gains in:	ECSEL (n = 294-321)	Non-ECSEL (n=129-138)
Knowledge and understanding of the process of design in engineering	3.04	2.55
Your ability to "do" design	2.85	2.33
Your ability to apply an abstract concept or idea to a real problem or situation	2.90	2.58
Your ability to describe a problem orally	2.85	2.51
Organize information into categories, distinctions, or frameworks that will aid comprehension	3.22	1.91
Ask probing questions that clarify facts, concepts, or relationships	2.95	2.29

Terenzini, P.T., Cabrera, A.F., Colbeck, C.L., Parente, J.M., Bjorklund, S.A. (2001). Collaborative Learning vs. Lecture/Discussion: Students' Reported Learning Gains. *Journal of Engineering Education*, 90:1, 123-130

Why RBIS?

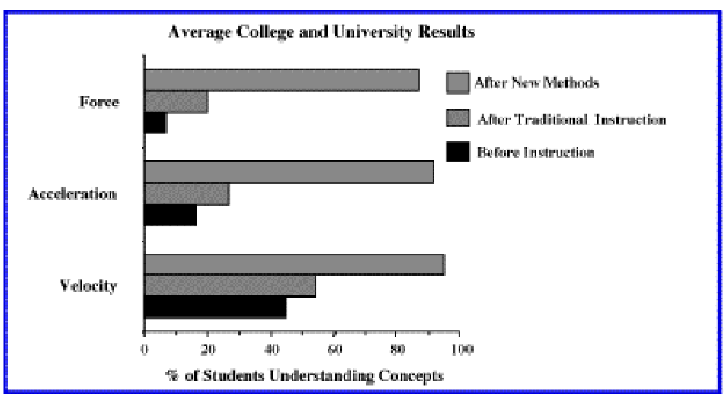


Figure 1. Composite assessment of US student understanding of kinematics (labeled Velocity and Acceleration concepts) and dynamics, as described by Newton's Laws (labeled Force concepts), using the Force and Motion Conceptual Evaluation. Dark bars show student understanding coming into beginning university courses, striped bars are after all traditional instruction. While the percentage of students who know concepts coming in can vary with the selectivity of the university, the effect of traditional instruction is to change the minds of only 5% to 15% of students. New methods described later in this paper result in up to 90% of students understanding concepts (lighter solid bars).

http://science.uniserve.edu.au/newsletter/vol13/sokoloff.html

How does using minute papers in courses work?

- **Findings:** "This result suggested, as we hypothesized, that the use of the one-minute paper improves student performance. Its coefficient implied that the use of the one-minute paper increased student performance by approximately .5 of a point on the postTUCE exam, ceteris paribus."
- **Findings:** "This evidence suggests that the benefit to students from using the one-minute paper does not depend on the instructor who implements it."
- **Findings:** "This evidence supported our initial hypothesis that the benefit to students from using the one-minute paper does not depend on their ability level."
- **Assertion:** "When asked by college teachers to identify the single pedagogical innovation that would most improve their teaching, Light (1990, 35) always responds with the one-minute paper, an idea that 'swamped all others.'"

Chizmar, J. F., and Ostrosky, A. L. (1998). The One-Minute Paper: Some Empirical Findings. *The Journal of Economic Education, 29*(1), 3–10

How does using minute papers in courses work?

- **Findings:** Overall results indicate that performance on subsequent essay quizzes was significantly higher by students who wrote one-minute papers than performance by students who did not write the papers.
- **Findings:** Of particular interest to instructors was that the increase in quiz scores when one-minute papers were not graded was significantly higher than when the one-minute papers were graded.

Almer, E. D., Jones, K., and Moeckel, C. L. (1998). The impact of one-minute papers on learning in an introductory accounting course. *Issues in Accounting Education, 13*(3), 485–495

Challenge-based Learning Pedagogies

- **Findings:** "Comparisons were made over a three-year period between student performance on knowledge-based questions in courses taught with taxonomy-based and challenge-based approaches to instruction. When performance on all questions was compared, CBI classes scored significantly better than control classes on 26 percent of the questions, while control classes outperformed CBI classes on eight percent of the questions, but there was no significant difference in overall performance."
- **Findings:** "… students in CBI classes performed significantly better than students in control classes on the more difficult questions (35 percent versus four percent)."

Roselli, R. J., and Brophy, S. P. (2006). Effectiveness of Challenge-Based Instruction in Biomechanics. *Journal of Engineering Education, 95*(4), 311–324.

There were significant differences between graduates of medical school using PBL and traditional lecture.

Attribute	
General fund of knowledge	.01
Physical diagnosis and history taking	.01
Ability to manage expected number of patients	.01
Medical judgment/ability to perform under pressure	.05
Quality of written presentations	.01
Quality of oral presentations	.01
Effectiveness with patients	.05

There were significant differences between graduates of medical school using PBL and traditional lecture.

Attribute	
Ability to teach medical students	.01
Communication with others on health-care team	.01
Level of maturity	.01
Willingness to accept responsibility	.01
Initiative	.01
Willingness to help others	not significant
Ability to accept criticism	.01

There were significant differences between graduates of medical school using PBL and traditional lecture.

Attribute	
Self-confidence	not significant
Sensitivity to psychosocial needs of patients	not significant
Projects qualities of a good physician	.01

Hoffman, K., Hosokawa, M., Blake, R., Headrick, L., & Johnson, G. (2006). Problem-based learning outcomes: Ten years of experience at the University of Missouri-Columbia School of Medicine. *Academic Medicine, 81*(7), 617-625.

Why Problem-based Learning?

Vernon, D. T .A., and Blake, R. L. (1993). Does Problem-Based Learning Work? A Meta-Analysis of Evaluative Research. *Academic Medicine, 68*, 550–563.

- PBL was found to be significantly superior with respect to students' program evaluations (i.e., students' attitudes and opinions about their programs) and measures of students' clinical performance
- PBL and traditional methods did not differ on miscellaneous tests of factual knowledge and tests of clinical knowledge
- Traditional students performed significantly better than their PBL counterparts on the National Board of Medical Examiners Part I examination-NBME I

Why Problem-based Learning?

- Dochy, F., Segers M., Van den Bossche, P., and Gijbels, D. (2003). Effects of Problem-Based Learning: A Meta-Analysis. *Learning and Instruction, 13*, 533–568
  - For skill development, the results are unequivocal: 14 studies found a positive effect and none found a negative effect, and the weighted average effect size was 0.460(±0.058).
  - For knowledge acquisition, seven of the studies analyzed found a positive effect and 15 found a negative effect, with weighted average effect size and 95 percent confidence interval -0.223 (±0.058). When the assessment of knowledge is carried out some time after the instruction was given, the effect of PBL positive.

Why Problem-based Learning?

Gijbels, D., Dochy, F., Van den Bossche, P., and Segers, M. (2005). Effects of Problem-Based Learning: A Meta-Analysis from the Angle of Assessment. *Review of Educational Research, (75)*1, 27–61.

- Three levels of the knowledge structure in assessment of problem solving:
  - (a) understanding of concepts
  - (b) understanding of the principles that link concepts
  - (c) linking of concepts and principles to conditions and procedures for application
- PBL had the most positive effects when the focal constructs being assessed were at the level of understanding principles that link concepts.

Why Problem-based Learning?

Capon, N. (2004). What's So Good About Problem-Based Learning? *Cognition and Instruction, 22*(1), 61-79

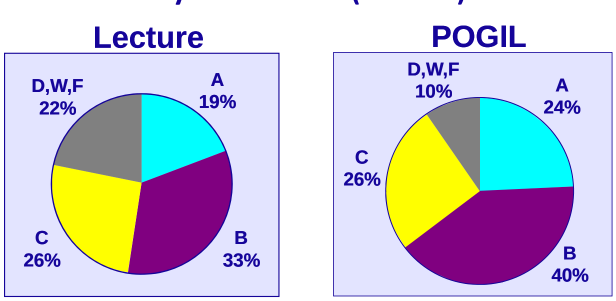
- Two intact classes, same instructor
- In 1 class, instruction was problem based for 1 concept. For a second concept, lecture/discussion was the exclusive method. In the other class, matching of concept and method (problem based or lecture/discussion) was reversed.
- At the initial assessment (6 weeks later), the lecture/discussion group showed superior learning for 1 concept and the groups performed equivalently for the other concept.
- At the later assessment (12 weeks later), however, the 2 groups showed equivalent ability to access each of the concepts, but each group showed superior explanation of the concept for which they had experienced problem-based learning.
- Results support the hypothesis of integration of new information with existing knowledge structures activated by the problem-based experience as the mechanism by which problem-based learning produces its benefits.

Why Active/Cooperative Learning?

- Felder, R.M., Felder, G.N., Dietz, E.J. (1998). A Longitudinal Study of Engineering Student Performance and Retention. V. Comparisons with Traditionally-Taught Students. *Journal of Engineering Education, 87*(4), 469-480

General Chemistry at Franklin & Marshall College

8 years of data (n = 905)



Data from classrooms of Moog, Farrell and Spencer
Chi squared = 40.9 alpha < 0.005
Comparing ABC vs. DFW

Farrell, J.J.; Moog, R.S.; Spencer, J.N. *J. Chem. Educ.* 1999, *76*, 570.

Small Liberal Arts College
General Chemistry

1993 ACS General Chemistry Final Exam
n = ~40 Students per year

Lecture (1994-2003)

Average % Correct = 55.5

Highest Average = 65.2 (2001)

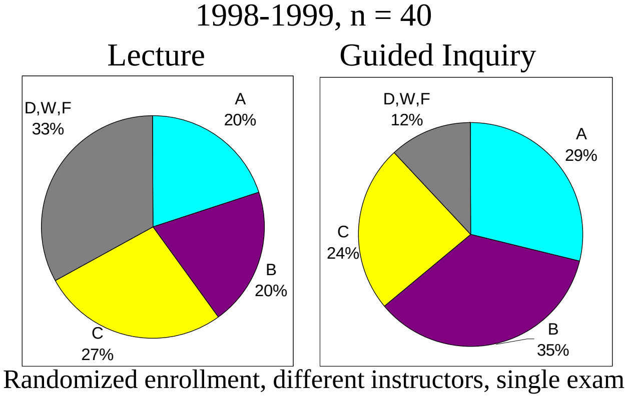
Lowest Average = 47.0 (2003)

POGIL Class (2004)

Average % Correct = 68.5

Organic Chemistry Grades
Washington College

1998-1999, n = 40

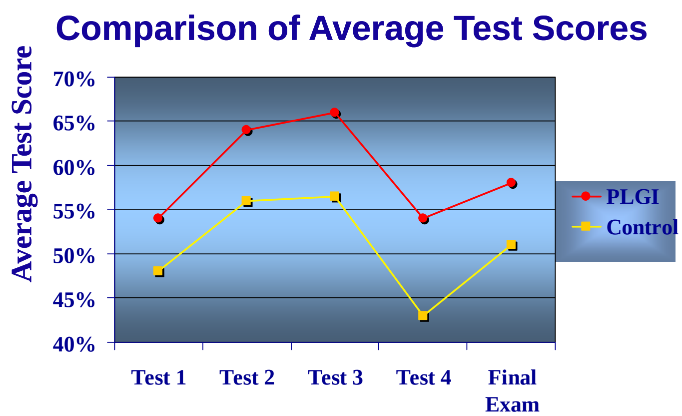


Randomized enrollment, different instructors, single exam given concurrently, prepared and graded by both instructors

Chi-squared = 7.1 alpha < 0.01

Peer Led Guided Inquiry in General Chemistry

Lewis, S.E. and Lewis, J.E. *J. Chem. Educ.* 2005, *82, 135-139.*



Addressing Student Resistance

- Resistance to externally-induced change is **inevitable**. Anticipate and prepare.
- Acknowledge changes, accompanying anxiety, and potentially negative prior experiences
- Emphasize benefits and fun. Lots on research on benefits of student engagement and active/cooperative learning.
- Plan to solicit feedback and respond constructively
- Encourage students to visit with you about their doubts
- Plan to talk one-on-one to most visibly

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Felder, R. M. and R. Brent (1996). "Navigating the Bumpy Road to Student–Centered Instruction." College Teaching **44**(2): 43–47.
Felder, R. M. and R. Brent (1994). Cooperative learning in technical courses: Procedures, pitfalls, and payoffs, ERIC Document Reproduction Service Report ED 377038. Washington, DC.
Cooper, J. L., J. MacGregor, et al. (2000). "Implementing Small-Group Instruction: Insights from Successful Practitioners." New Directions in Teaching and Learning **81**: 64-76.

Efficacy of Small Group Learning

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Efficacy of Active Learning

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