THE ROOTS OF STEM EDUCATION

ROCHESTER INSTITUTE OF TECHNOLOGY

APRIL 21, 2010

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PROJECT KALEIDOSCOPE (PKAL)

Leading advocate for building and sustaining strong undergraduate programs in STEM since 1989

Extensive network of ~ 2000 faculty members (F21 & others) and leaders at over 750 colleges and universities in the U.S.
A kaleidoscope creates a multitude of patterns in response to change, so our agenda encompasses a multiplicity of approaches that can be adapted to specific circumstances and institutional environments.
A LOOK BACK ...
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... Science and mathematics education works wherever it takes place within an active community of learners, where students work collaboratively in groups of manageable size, and where faculty are deeply committed to teaching, devoted to student success, and convinced that all students can learn. It works where learning is active, hands-on, investigative, and experiential, and where the curriculum is rich in laboratory experiences, steeped in the methods of scientific research as it is practiced by professional scientists. This approach works for women, for minorities, for all students.
-- Dan Sullivan, 1991, PKAL Volume I: Building Natural Science Communities
CALVIN AND HOBBES

OH NO! EVERYTHING HAS SUDDENLY TURNED NEO-CUBIST!

IT ALL STARTED WHEN CALVIN ENGAGED HIS DAD IN A MINOR DEBATE. SOON CALVIN COULD SEE BOTH SIDES OF THE ISSUE! THEN POOR CALVIN BEGAN TO SEE BOTH SIDES OF EVERYTHING!

THE TRADITIONAL SINGLE VIEWPOINT HAS BEEN ABANDONED! PERSPECTIVE HAS BEEN FRACUTURED!

THE MULTIPLE VIEWS PROVIDE TOO MUCH INFORMATION! IT'S IMPOSSIBLE TO MOVE! CALVIN QUICKLY TRIES TO ELIMINATE ALL BUT ONE PERSPECTIVE!

IT WORKS! THE WORLD FALLS INTO A RECOGNIZABLE ORDER!

YOU'RE STILL WRONG, DAD.
THE CURRENT LANDSCAPE
THE CURRENT LANDSCAPE

iPad is here.
THREE QUESTIONS

What do they & should they know?
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How shall we teach (how will they learn)?
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What do they & should they know?

How will we (& they) know?

How shall we teach (how will they learn)?
**Scenario A:** Dr. Young has diligently created an visually appealing PowerPoint lecture, complete with animations, images from the textbook and even some primary data. She provides a PDF of the slides to students on the class website in advance so they don’t have to copy it all down and can focus on learning. They seem happy and engaged during.

However, when she gives them an exam question where she asks them to draw conclusions from provided data, only one student can do it. She shrugs and says, “They never get that question right.”

-Analyze this situation from a learning perspective.
**Scenario B:** A graduate teaching assistant is the instructor for one section of a lower division biology lab course where students follow the directions in their lab books to carry out the assigned experiment on enzymes. Students are provided with all the reagents they need, plus detailed step-by-step instructions to carry out the desired reactions which are measured by a pH change in the reaction.

A student walks up to the TA with a reaction tube that has turned from no color to a yellow color. He asks the TA why. The TA diligently explains that the yellow color is an indication of a pH change resulting from the activity of the enzyme in the tube.

- Analyze this situation from a learning perspective.
Learning builds on existing knowledge
Learning requires active cognitive challenges
Learning is structured
Learning occurs in context & is relevant to the learner
Learning is reflective (metacognition)
Learning is social

HOW LEARNING HAPPENS

Concrete experience
Active Testing
Reflective observation
Abstract hypothesis

Learning is a discovery process for the learner.
Learning is a discovery process for the learner.
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We must abandon the implicit assumption that all brains are the same and so passing along what is clear to us (experts) will be clear to the novice student, and if it fails, it is an indication that the students are simply incapable. We must instead come to recognize that mastery of a subject is much more a process of restructuring the brain than simply of transferring knowledge. -- Carl Weiman (The Curse of Knowledge (2007) The Back Page, APS News, 16 #10)
THE CYCLE OF LEARNING AND ADULT DEVELOPMENT

EPISODES OF LEARNING

INTERVENTIONS OF TEACHING

MATURE THINKER WHO IS “CRITICALLY AUTONOMOUS”
AND IN MY VIEW, JEFFERSON'S DEFENSE OF THESE BASIC RIGHTS LACKED CONVINCING. OKAY, ANY DISCUSSION OF WHAT I'VE COVERED SO FAR?

SCRIBBLE! SCRIBBLE! SCRIBBLE!

OF COURSE NOT. YOU'RE TOO BUSY GETTING IT ALL DOWN.

SCRATCH! SCRATCH! SCRATCH!

NO, SCRATCH THAT! THE CONSTITUTION ITSELF SHOULD NEVER HAVE BEEN RATIFIED! IT'S A DANGEROUS DOCUMENT! ALL POWER SHOULD REST WITH THE EXECUTIVE! WHAT DO YOU THINK OF THAT?

SCRATCH! SCRATCH! SCRATCH!

JEFFERSON WAS THE ANTICHRIST! DEMOCRACY IS FASCISM! BLACK IS WHITE! NIGHT IS DAY!

SCRIBBLE! SCRIBBLE! SCRIBBLE! SCRIBBLE! SCRIBBLE!

TEACHING IS DEAD.

BOY, THIS COURSE IS REALLY GETTING INTERESTING.

YOU SAID IT, I DIDN'T KNOW HALF THIS STUFF.
Knowledge of Human Cultures and the Physical and Natural World
- Through study in the sciences and mathematics, social sciences, humanities, histories, languages, and the arts
  
  Focused by engagement with big questions, both contemporary and enduring

Intellectual and Practical Skills, including
- Inquiry and analysis
- Critical and creative thinking
- Written and oral communication
- Quantitative literacy
- Information literacy
- Teamwork and problem solving
  
  Practiced extensively, across the curriculum, in the context of progressively more challenging problems, projects, and standards for performance

Personal and Social Responsibility, including
- Civic knowledge and engagement—local and global
- Intercultural knowledge and competence
- Ethical reasoning and action
- Foundations and skills for lifelong learning
  
  Anchored through active involvement with diverse communities and real-world challenges

Integrative Learning, including
- Synthesis and advanced accomplishment across general and specialized studies
  
  Demonstrated through the application of knowledge, skills, and responsibilities to new settings and complex problems

AAC&U LEAP Outcomes: Liberal education for America’s promise
THREE QUESTIONS

What do they & should they know?

How shall we teach (how will they learn)?

How will we (& they) know?
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- Use institutional resources and instruments when possible (e.g., NSSE)
Three identical plates of radish seeds are incubated under three different conditions, with results as shown. How will the dry weights of the three plates compare at the end of the experiment?

A) $1 < 2 < 3$
B) $1 < 3 < 2$
C) $1 = 3 < 2$
D) $3 < 1 < 2$
E) $1 = 2 = 3$

EBERT-MAY, ET AL. 2003, BIOSCIENCE
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The largest gain in learning productivity in STEM will come from convincing the large majority of STEM faculty that currently teaches by lecturing to use any form of active or collaborative instruction.

-- James Fairweather (2009) Report to the National Academies Board on Science Education
AN EXAMPLE CLASS STRUCTURE

Miller et al. (2008) Science 322:1329
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Textbook Figures vs. Real Data

Figure 12.3 from Pierce, Benjamin, 2005, *Genetics: A Conceptual Approach*, WH Freeman, New York.


**PASSIVE LEARNING**

**ACTIVE LEARNING**

CASE STUDIES WRITTEN USING PRIMARY DATA
Respecting students as thinkers means we need to reveal, not hide, the intellectual journeys we have taken, and make transparent the intellectual transformations we have undergone. Respecting students as thinkers thus involves a number of changes, including meeting students where they are, so that they trust us to develop their intellectual skills and expand their knowledge base. -- Tim Clydesdale (Wake Up and Smell the New Epistemology, Chronicle of Higher Education, January 23, 2009)
What is one lesson learned from this afternoon that you will apply in your classroom, department, college or at the institutional level?
RESOURCES


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Wieman, C. et al., *Transforming Science Education at Large Research Universities*, Change, March/April 2010