Composing a Course from an Array of Teaching Methods

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Traditional teaching methods

- Lecture
- Assigned Reading
- Class Discussion
- Lab experiment (verification)
- homework problems
- quizzes

Lecture

Pros and Cons

Scott Freeman *et al*. Active learning increases student performance in science, engineering, and mathematics. **PNAS** 2014, 111(23) 8410-8415.

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate STEM courses under traditional lecturing versus active learning. These results indicate that average examination scores improved by about 6% in active learning sections, and that students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning.

Cognitive science illuminates learning processes

- Repeated engagement leads to long-term memory
- **Constructivism**: new information must be fit into existing knowledge

Sonata form

The Scientific Method

The Learning Cycle

1. **Exploration**: observe phenomena, look for patterns

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2. **Term Introduction**: learn vocabulary to describe pattern

The Learning Cycle

1. **Exploration**: observe phenomena, look for patterns

2. **Term Introduction**: learn vocabulary to describe pattern

3. Application: use concept in new context (confirm idea or discover misconception)

Learning Cycle in Lecture

1. **Exploration**: Describe a piece of paper.

Learning Cycle in Lecture

2. **Term Introduction**:
Our description of paper is a list of **Properties**.

Physical Properties of a sample are observed by applying a force to it.

Chemical Properties of a sample are observed by doing a reaction that changes it into a new substance.

Learning Cycle in Lecture

3. **Application**:

List physical and chemical properties of paper.

Learning Cycle in Lecture

2. **Term Introduction**:

Properties that depend on the amount of paper are **Extrinsic Properties**.

Properties that do not depend on the amount of paper are **Intrinsic Properties**.

Learning Cycle in Lecture

3. **Application**:

What properties of paper are **Extrinsic**?

What properties of paper are **Intrinsic**?

Traditional Organization

Start with technical terms and definitions,
Then give examples.

(Abstract to Concrete)

Advantage: lecture notes are very organized.

Traditional Organization

I. Adiabatic Processes.

A. Definition

Adiabatic: a process in which no heat is transferred.

$$q = 0$$

.

Traditional Organization

I. Adiabatic Processes.

A. Definition

Adiabatic: a process in which no heat is transferred.

$q = 0$

B. Expansion of a gas against constant pressure.

Since $q = 0$, $C_V \Delta T = -p\Delta V$.

$\Delta T = -p\Delta V/C_V < 0$ since pressure, ΔV and C_V are positive.

That is why gases cool when expanded through a jet nozzle.

Learning Cycle in Music

1. Experience

2. Explanation

3. Extrapolation

Backward Design

1. Define learning objectives
2. Decide how to measure accomplishment of each objective
3. Choose teaching methods suited to each objective

Active learning methods

- ConcepTests
- Small group “think-pair-share”
- Clicker questions
- Student reflections “muddiest point”
- Collaborative learning
- Inquiry laboratories
- Case studies
- Service learning projects

General Chemistry course offers many ways to learn

- read textbook,
- watch/listen to lectures,
- watch demonstrations,
- design, perform experiments,
- write lab reports,
- solve problems,
- participate in group discussions.

Questions for study

- Do students recognize the learning that results from participation in various course components?

- Are student perceptions influenced by their preferred learning styles?

Experimental Design

- General Chemistry II
- Introductory survey on learning styles
- Reflection practice: minute papers
- Kinetics unit
  - Three 90 minute **lecture** periods
  - Two 60 minute **discussion** periods
  - Two 3 hour **lab** periods
- Daily, online surveys on learning gains

Daily Survey

How much did the activity help with each of the specific learning objectives for the kinetics unit?

1 = no help, 2 = a little help, 3 = moderate help, 4 = much help, 5 = great help

modeled on SALG (Student Assessment of their Learning Gains) www.salgsite.org

Learning Objectives

- End of chapter list of 35 objectives
- Sorted into cognitive process

  remember, understand, apply,

  analyze, evaluate, create
- and type of knowledge

  factual, conceptual, procedural
- Exam questions matched to objectives

Anderson *et al.* (2001) *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Addison Wesley Longman.

Sample Learning Objectives

	Objective from textbook	***process***	***knowledge***
1a	Recognize/define reaction rate	Remember	factual
6a	Recognize collision theory	Remember	conceptual
1b	Explain why rate depends on concentration	Understand	conceptual
3a	Describe information needed for rate law	Analyze	conceptual
3b	Use initial rates to determine rate law	**Analyze** **Apply**	factual procedural
3c	Use rate law to calculate reaction order	Apply	procedural
7c	Is a mechanism consistent with rate law	Evaluate	conceptual
4d	Plan an experiment to find a rate law	Create	factual
7d	Construct a reaction mechanism	Create	conceptual

Most helpful class for each goal

	process	***knowledge***	**lec 1**	**lec 2**	disc 1	**lec 3**	lab 1	disc 2	lab 2
1a	Remember	factual	■	■					
6a	Remember	conceptual		■					
6e	Remember	conceptual				■			
1b	Understand	conceptual	■	■					
1c	Understand	conceptual	■						
1d	Understand	conceptual	■						
2a	Understand	conceptual		■					
4f	Understand	conceptual		■					
5a	Understand	conceptual				■			

	process	***knowledge***	lec 1	lec 2	disc 1	lec 3	lab 1	disc 2	lab 2
2b	Apply	procedural							
3c	Apply	procedural							
4a	Apply	procedural							
4c	Apply	procedural							
4e	Apply	procedural							
5d	Apply	procedural							
7e	Apply	procedural							
3b	Analyze Apply	factual procedural							
4b	Analyze Apply	factual procedural							

	process	***knowledge***	lec 1	lec 2	disc 1	**lec 3**	**lab 1**	**disc 2**	**lab 2**
2c	Analyze	conceptual							
3a	Analyze	conceptual							
7b	Analyze	conceptual							
8b	Analyze	conceptual							
8c	Analyze	conceptual							
7c	Evaluate	conceptual							
4d	Create	factual							
7d	Create	conceptual							

End of Unit Survey

I. How much did each type of activity help with the learning objectives for the unit? (5 point scale)

II. Are there any activities that you think should be done more often?

III. Are there any activities that you think should be done less often?

Rankings for required activities

Doing clicker questions in lecture	4.4	+
Doing end of chapter problems	4.0	+
Listening & taking notes in lecture	3.9	+
Viewing demonstrations in lecture	3.8	0
Reading the textbook	3.7	+
Collaborative guided inquiry worksheets	3.7	0
Collaborative analysis of lab data	3.5	0
Collaborative performance of experiment	3.3	-
Collaborative design of lab experiment	3.2	-
Reviewing objectives with daily surveys	2.9	-

Many activities were highly rated

On average, students assigned

- “great help” to three activities
- “much” or “great help” to seven activities

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Top 25% of students on exam

- > four activities received highest rating

Lowest 25% of students on exam

- < three received highest rating

U Michigan surveyed students at each exam on use of learning resources

Students who improved over the semester:

Attended lectures, read book, did problems

AND

did any three other activities:

(listen to podcasts, attend TA led recitations, looked at websites, . . .)

What if you only make one change?

260 student general education class in psychology – students can be isolated

6 hours training on teaching diverse classes

*listened to experiences of students of color *

Change: each period students get into pairs to answer a question, writing and discussing

It's hard to make even one change

Scholars followed instructors for the semester after the workshop using interviews, written reflections, focus group

Concerns:

- time to revise class plan
- less class time to cover everything
- expert on discipline, not pedagogy

Why did they persevere?

- enjoyed learning about students, pedagogy
- mid-semester reflections
- collaborative learning community

Effect on Student Success

	Fall 2010	Fall 2011
Average grade	2.42	2.69
Overall DFWs	19.7% (N = 244)	12.6% (N = 261)
DFW 1st Gen College Students	22.4% (N = 134)	16.7% (N = 138)
DFW Students of Color	59.1% (N = 22)	37.9% (N = 29)
DFW Female Students	15.6% (N = 167)	8.6% (N = 185)
DFW Male Students	22.5% (N = 80)	20% (N = 70)

Acknowledgements

- Wisconsin Teaching Fellow & Scholar Program
- UWS Office of Professional Instructional Development
- UW Oshkosh Center for Excellence in Teaching and Learning
- UW Oshkosh Faculty Development Fund
- Dr. Jennifer Considine, Dr. Jordan Landry, Dr. Yoko Mogi-Hein, Dr. Marguerite Parks, Dr. Paul Van Auken, Dr. Erin Winterrowd, Dr. Sandra Neuendorf, Dr. George Olsen, and Chem 106 students