

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

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

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

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

Learning Cycle in Music

1. Experience
2. Explanation
3. Extrapolation

Newer teaching methods

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

U of M 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, . . .)

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 this 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

Felder-Silverman model of Learning Styles

44 item survey, 4 dimensions,

Developed for chemical engineering students

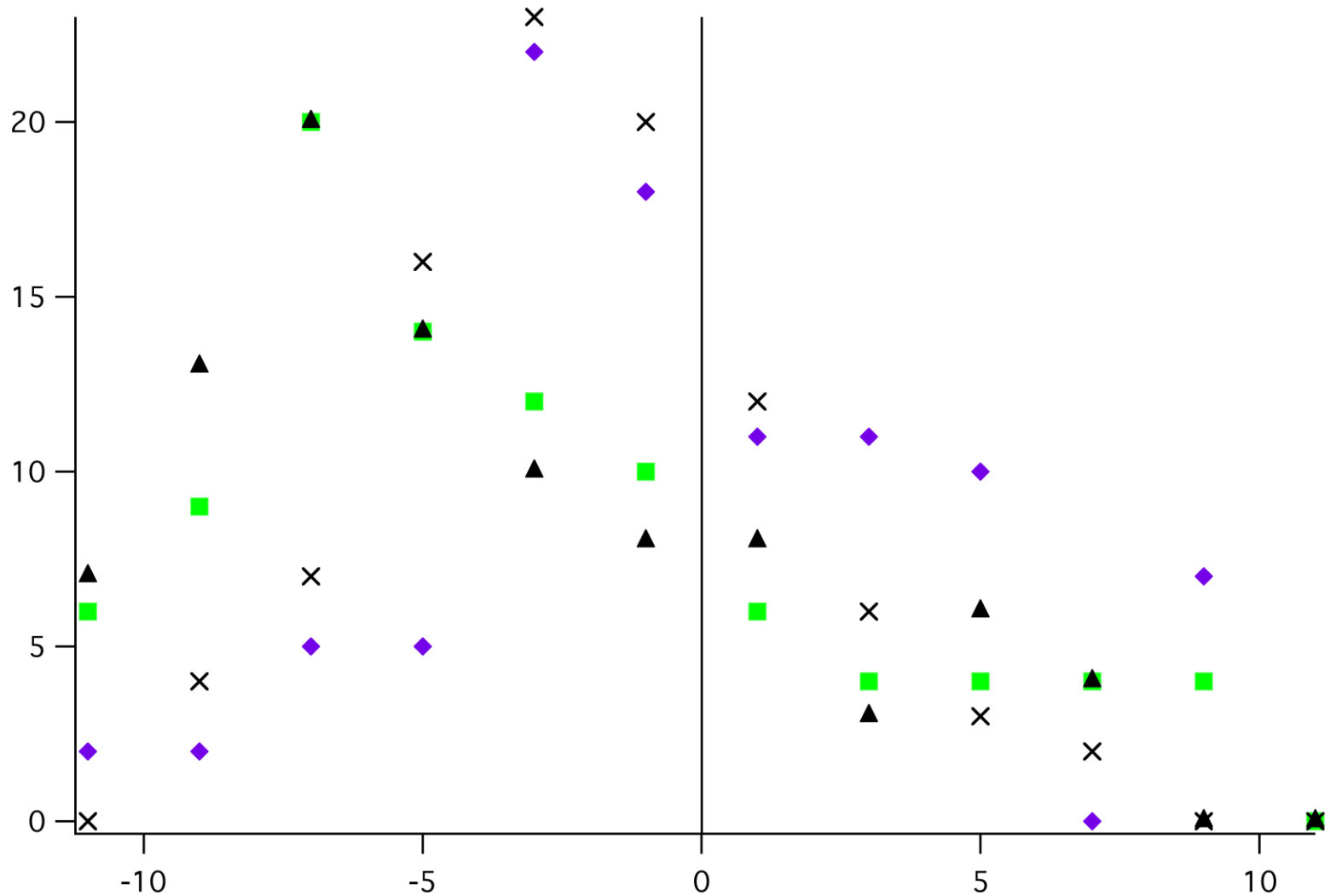
Active to Reflective

Sensing to Intuitive

Visual to Verbal

Sequential to Global

Student Learning Styles Distribution



◆ Active to Reflective (0)
▲ Visual to Verbal (-4)

■ Sensing to Intuitive (-3)
× Sequential to Global (-2)

Daily Survey

I. What type of learning was accomplished by the activity?

from Francisco, J. S., Nicoll, G., Trautmann, M.,
J. Chem. Educ. **75**, 210-213 (1998).

II. 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

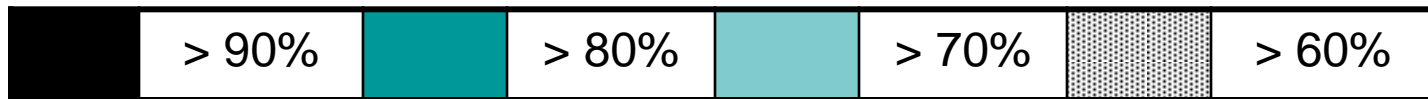
- End of chapter list of 35 objectives
- Sorted into cognitive process
remember, understand, apply,
analyze, evaluate, create
- and type of knowledge
factual, conceptual, procedural
- Exam questions matched to objectives

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

	<i>Objective from textbook</i>	<i>process</i>	<i>knowledge</i>
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

What was accomplished?	lec 1	lec 2	disc 1	lec 3	lab 1	disc 2	lab 2
Provided new information	Black	Black	Light Blue	Black	Dark Blue	Light Blue	Dark Blue
Pinpointed important or difficult concepts	Dark Blue	Dark Blue	Light Blue	Dark Blue	Light Blue	Dark Blue	Dark Blue
Identified lack of understanding	White	Light Blue	Light Blue	Stippled	Stippled	Dark Blue	Dark Blue
Clarified important or difficult points	White	White	Stippled	Stippled	Stippled	Dark Blue	Light Blue
Answered questions regarding the material	Light Blue	Light Blue	Dark Blue	Black	Dark Blue	Dark Blue	Dark Blue
Organized material in meaningful ways	Black	Light Blue	Light Blue	Black	Stippled	Dark Blue	Light Blue
Modeled ways to look at the material	Dark Blue	Light Blue	Dark Blue	Dark Blue	Dark Blue	Dark Blue	Dark Blue
Made the material more interesting	Light Blue	White	White	White	Stippled	White	Stippled
Provided opportunities to relearn concepts	White	Stippled	White	Light Blue	Light Blue	Black	Dark Blue
Assessed readiness for next topic	White	Light Blue	White	Light Blue	White	Stippled	Stippled
Assessed readiness for exam	White	White	White	White	White	Stippled	White



Most helpful class for each goal

	<i>process</i>	<i>knowledge</i>	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							

	<i>process</i>	<i>knowledge</i>	lec 1	lec 2	disc 1	lec 3	lab 1	disc 2	lab 2
5b	Understand	conceptual							
5c	Understand	conceptual							
6b	Understand	conceptual							
6c	Understand	conceptual							
6d	Understand	conceptual							
6f	Understand	conceptual							
6g	Understand	conceptual							
7a	Understand	conceptual							
8a	Understand	conceptual							

	<i>process</i>	<i>knowledge</i>	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							

	<i>process</i>	<i>knowledge</i>	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?

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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On average, students assigned

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

Top 25% of students on exam

- > four activities received highest rating

Lowest 25% of students on exam

- < three received highest rating

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	-

Optional activities

Asking questions outside of class (office hours, email)	2.9
Studying with classmates	2.9
Participating in workshop (collaborative problem solving)	2.7

Reponses to activities did not correlate with any dimension of the learning style model.

What should be done more often?

1. Clicker questions (in lecture)
2. Example problems (in lecture)

What should be done less often?

1. One-third could not choose anything!
2. Writing lab reports

Backward Design

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

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