Designing and using self-assessment, testing, and evaluation in undergraduate chemistry teaching and learning

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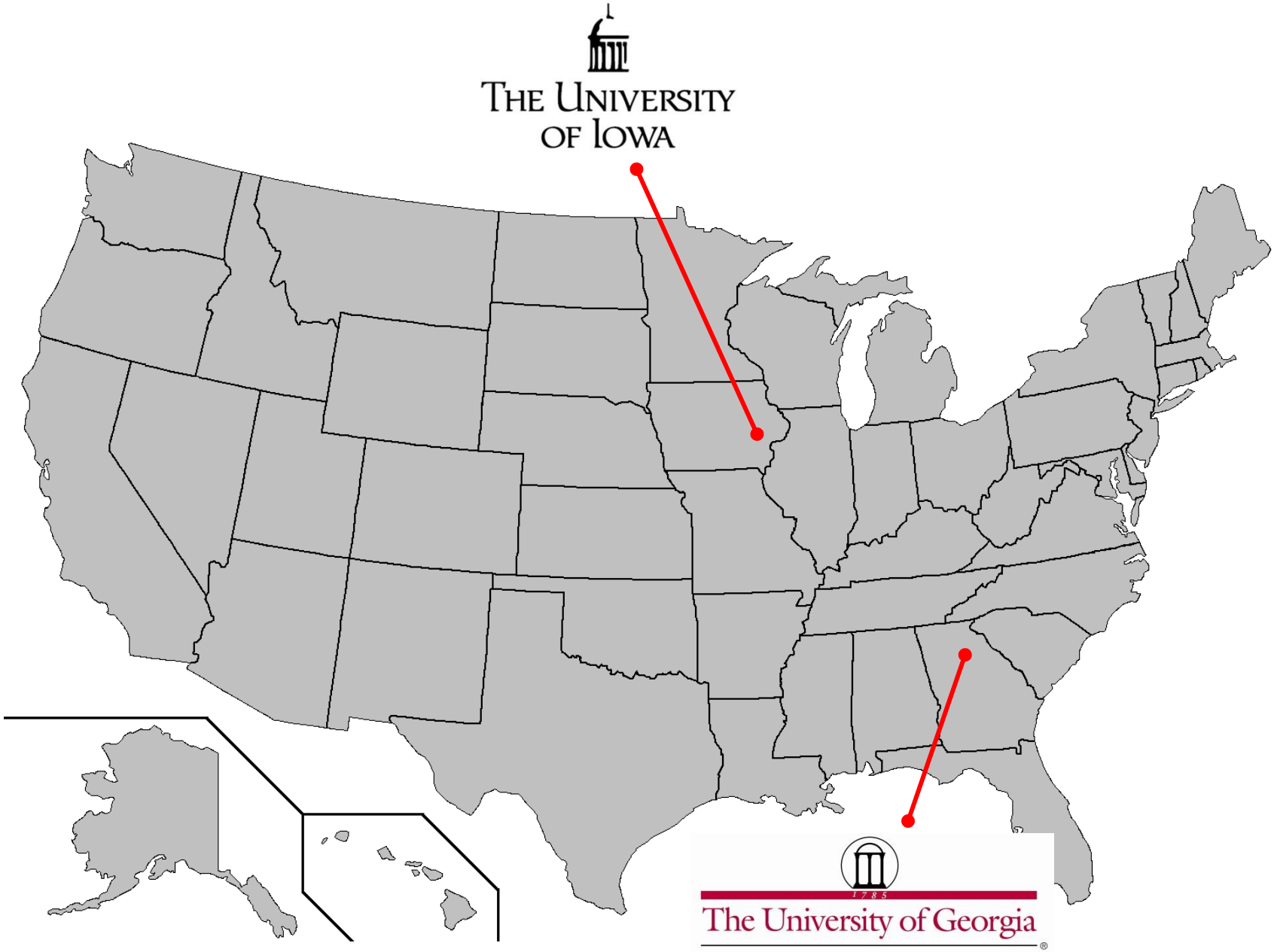

THE UNIVERSITY OF IOWA
1785
The University of Georgia

Iowa and Chemistry

Univ. of Iowa: ~30,000 students, ca. 21,000 undergrads

- Colleges: Liberal Arts & Sciences, Business, Engineering, Education
- Professional schools: Pharmacy, Dentistry, Medicine, Law, Public Health

Undergraduates

- entering class: ca. 4000-4500
- top 50% of secondary school
- ACT composite (mid-50%): 23-27 [SAT: 1090-1300]

First year students in chemistry

- Technology & Society (GE credits for non-science majors)
- Preparatory chem (one semester)
- Principles of Chemistry (two semesters) ←

Principles of Chemistry Sequence [~2002]

Course components

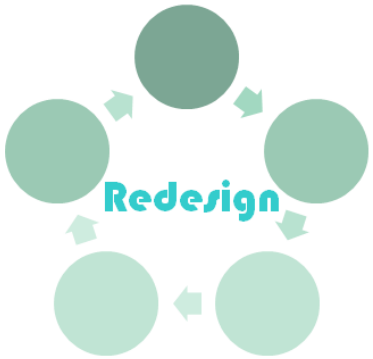
- Lecture: 3 × 1-hr/wk, large auditorium venue (350-400), instructor
- Recitation: 1 × 1-hr/wk, small class (25-30), grad student
- Laboratory: 3 × 1-hr/wk, small (24), grad student

Assessment / Self-assessment

- 4 × 1-hr exams, 1 × 3-hr comprehensive final [written, multiple choice]
- laboratory: pre-assignment, post-report
- graded homework [paper or electronic]

Demographics

- 15 week semester, some holidays/breaks
- 900-1100 students; ~50:50 M:F



Based on redesign of courses…

Story elements…

- need(s)
- conflict
- planning
- support
- implementation
- assessment

Needs

Components
needs
conflict
planning
support
implementation
assessment

Student success issues

- high rate of D, F, W grades

Concerns from programs / majors about courses as prerequisite

- Engineering, Pharmacy

Student dissatisfaction

- “weedout” vs gatekeeper

Summary of the Redesign

Enrolled students

- evaluation of preparedness
  - math and chemistry content knowledge
- better management of expectations

Curriculum / content

- laboratory better integrated with lecture
- implement computer-based homework (practice, self-assessment?)
- change discussion / recitation section model
- some pedagogical changes in lecture
- no changes in scope of content covered

Assessment of Outcomes

Components
needs
conflict
planning
support
implementation
assessment

Formative

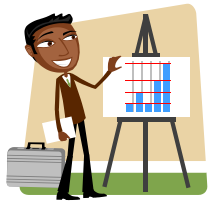
- student focus groups and interviews
- comparison scores, statistics

Summative

- decide on items during planning
- outcomes includes students, faculty, programs, etc.

Affective side

- includes motivation, attitudes, perceptions and values
- anecdotal results
  - Use of various tutoring programs diminished or eliminated
  - Neither engineering nor pharmacy seceded



Scientists & Administrators Like Numbers

Formative

- student focus groups, course “Board of Directors”
- Chemistry Diagnostic Test CDT used as pre- & post-test
- “Brown-bag” group

Summative

- common final exam questions [20 from previous final, both conceptual & algorithmic questions]
- ACS Exams Institute standard exams [set of questions; nat’l norms]
- CDT as pre- and post-test
- Grades [DFW drops!!]
- Campus tutoring programs [various, demand drops]
- Constituencies [feedback from colleges]

Description of Assessment Items

Chemistry Diagnostic Test (written by us)

- 30 questions: paired conceptual and algorithmic
- delivered electronically: course mgmt system or proprietary browser
- developed over multiple semesters (used as pre- and post-test in class)

ACS Exams Institute (written by nat'l committee)

- paper
- General Chemistry I exam (70 multiple choice questions; 110 minutes)
- variety available: per semester, per year, conceptual only, paired

Course final exam (written by instructors)

- paper
- multiple choice (40-50 questions; 2 hours)

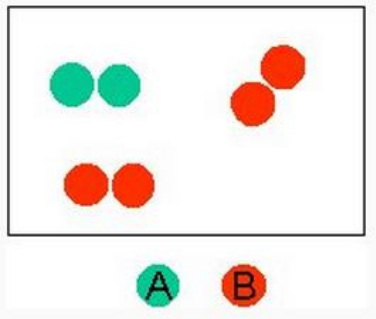
Chemistry Diagnostic Test

Topics

- acid/base, atomic structure, concentration, electronegativity, heat of combustion, ideal gas, Lewis structure, limiting reagent, mole, periodicity, periodic table, reactions, states of matter, stoichiometry, structure, unit conversion

Examples

- Consider the reaction: C (*s*) + O_2 (*g*) → CO_2 (*g*)
  If 0.2 moles of carbon are allowed to react with 0.4 moles of molecular oxygen, how many moles of CO_2 are formed?
- The diagram shows two reagents A and B in different colors. Each sphere represents an atom. Joined spheres represent molecules. The appropriate number of each atom are drawn in the box. Which of these is correctly represented by the figure?



Course Final Questions

Examples

Iodine and chlorine combine to form the interhalogen compound I-Cl according to the equation:

$I_2\,(g) + Cl_2\,(g) \quad 2\ I\text{-}Cl\,(g)$

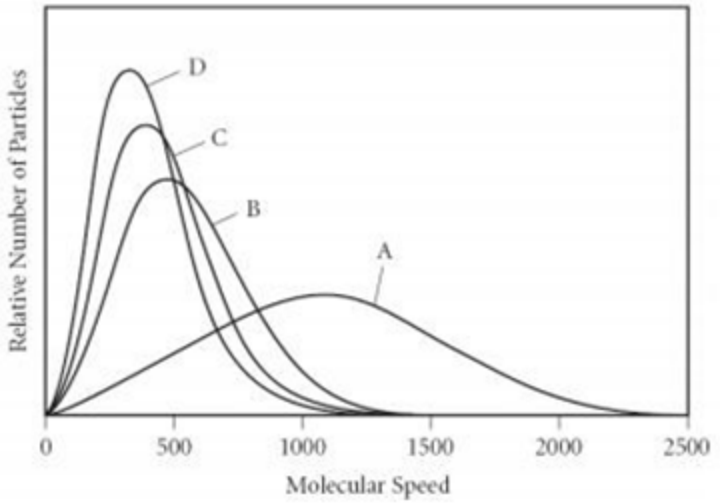
A sample of I-Cl is introduced to a flask, and equilibrium is established when 18% of it remains. What is K_p for the reaction?

Which of the trends is consistent with the molecular speeds in the diagram?

I) Molar mass increases from A to D

II) Density decreases from A to D

III) Temperature increases from A to D



Some Outcome Numbers…

- DFW rates

	% Withdraw	% D + F	% D + F + W
baseline	8 - 20	~15	23 - 35
Fall 2002	4	9	13

- Iowa Chem Diagnostic Test (2002)

	Pretest (1st week)	*Post-test (last wk)*	
N =	756 (92%)	690	641 took both
score =	18.5 ± 4.6	24.7 ± 3.9	diff = 6.2 (t = 34.9, p < 0.0001)

- Common exam questions
  - Previous: 12.6 avg
  - F'02: 12.5 ± 3.4 (N = 772); 11 net gain, 9 loss

Longitudinal Student Data

Survey of students

- at the beginning of 2nd semester about experience in first semester
  - caveat: only includes those who take both courses
- self-reporting
  - Do they know how they learn?
  - On what do they base their answers?

Question 1

Which of the following factors most helped you learn chemistry and succeed in 4:011?

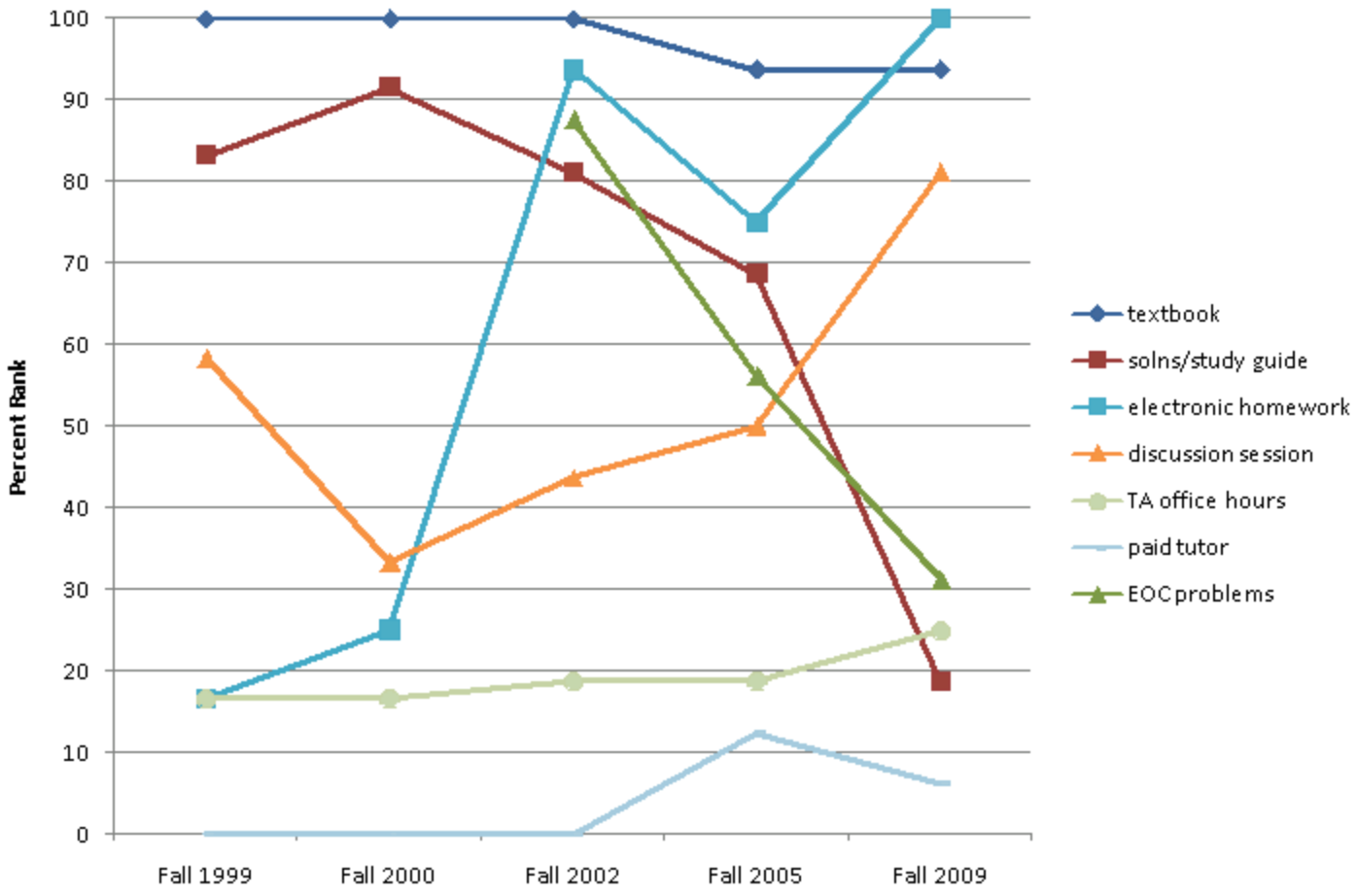
- ✓ textbook
- ✓ solutions manual/study guide with text
- ✓ CD-ROM with text
- ✓ text website (NOT course website)
- ✓ lecture/presentation content
- ✓ lecturer's ability to make content interesting
- ✓ lecturer's ability to make content relevant
- ✓ course website (ICON)
- ✓ demonstrations in class (live or virtual)
- ✓ end of chapter problems
- ✓ electronic homework (WebAssign, MGC or other)
- ✓ discussion section
- ✓ case study sessions [preparing for the experiments]
- ✓ laboratory sessions [doing the experiments]
- ✓ study group
- ✓ paid tutor
- ✓ friend(s)
- ✓ TA office hours

What helped you learn and succeed?

avg score (% completing item)

1= least to 10 = most effective	***Fall 1999 N = 261***	***Fall 2000 N = 228***	***Fall 2002 N = 204***	***Fall 2005 N = 228***	***Fall 2009 N = 460***
textbook	7.7 ± 2.0 (100%)	8.1 ± 1.7 (100%)	7.7 ± 2.1 (100%)	7.3 ± 2.3 (99%)	7.2 ± 2.4 (99%)
solns/study guide	6.8 (79%)	7.4 (90%)	7.0 (93%)	6.6 (75%)	4.5 (65%)
CD-ROM w/ text	4.0 (68%)	2.5 (56%)	2.4 (56%)	1.6 (34%)	1.6 (30%)
text website	---	---	2.7 (55%)	2.5 (40%)	3.3 (43%)
lecture content	5.6 (99%)	6.5 (99%)	6.6 (98%)	7.4 (98%)	6.7 (96%)
interesting	4.5 (95%)	5.0 (97%)	6.4(98%)	6.5 (95%)	6.0 (94%)
relevant	5.7 (96%)	6.3 (96%)	6.6 (99%)	7.0 (96%)	6.5 (95%)
course website	---	---	6.5 (94%)	5.9 (89%)	6.3 (89%)
EOC problems	---	---	7.1(94%)	6.4 (91%)	5.7 (73%)
written homework	6.6 (98%)	5.4 (72%)	---	---	---
electronic homework	4.1 (42%)	3.6 (76%)	7.6 (98%)	7.0 (96%)	7.5 (98%)
discussion session	5.9 (97%)	4.3 (87%)	5.2 (98%)	6.0 (95%)	6.8 (98%)
case study session	---	---	4.9 (98%)	5.8 (96%)	6.4 (97%)
laboratory session	---	---	4.5 (98%)	5.3 (95%)	5.9 (96%)
TA office hours	4.1 (51%)	3.4 (52%)	3.0 (33%)	4.8 (46%)	5.4 (52%)
study group	5.9 (49%)	4.3 (46%)	4.7 (58%)	5.0 (45%)	6.0 (53%)
paid tutor	3.5 (18%)	2.4 (26%)	1.9 (24%)	4.3 (18%)	2.7 (23%)
friends	6.8 (83%)	6.3 (73%)	6.1 (69%)	7.0 (80%)	6.8 (78%)

What helped you learn and succeed?



Fall '02 redesign implemented

Question 2

Describe your time investment: Report the avg number of hrs per wk [7 x 24 = 168]

✓ working on gen chem (outside of lecture & discussion section)

✓ using WebAssign software [I used it ___ alone or ___ in a group]

Describe your weekly schedule. Please report average number of hours per week.

✓ in class (all courses)

✓ studying out of class (all courses)

✓ entertainment

✓ living (eat, sleep, shower, laundry, grocery shopping, etc.)

✓ working at a job

✓ other

Demographics

✓ gender

✓ grade

✓ % lectures attended

How do you spend your time?

- more time in gen chem?
- more time on e-homework?

Weekly Schedule (avg hrs)	***Fall 2000, hrs***	***Fall 2002, hrs***	***Fall 2005, hrs***	***Fall 2009, hrs***
in class (all courses)	16 ± 4	18 ± 5	18 ± 4	19 ± 7
studying out of class (all courses)	19 ± 11	23 ± 15	20 ± 10	23 ± 15
(gen chem)	5.6 ± 4.1	5.0 ± 3.2	5.0 ± 3.0	7.8 ± 6.2
(e- homework)	4.0 ± 4.2	2.9 ± 2.0	3.0 ± 1.5	4.4 ± 4.2
working at a job	14 ± 7 (35%)	15 ± 8 (30%)	15 ± 10 (28%)	5 ± 11 (32%)
entertainment	14 ± 10	22 ± 18	17 ± 11	21 ± 18
“living”	77 ± 30	70 ± 27	77 ± 23	76 ± 36

Some references…

“General chemistry student surveys: Longitudinal data about which factors helped them learn,” Norbert J. Pienta, in *Investigating Classroom Myths through Research on Teaching and Learning*, Diane Bunce (ed), Washington (DC): *ACS Symposium Series #1074*, **2011** [student learning factors in general chemistry (Iowa’s Principles courses)]

“From Course Redesign to Curricular Review: Assessment in Chemistry at the University of Iowa,” Norbert J. Pienta, in *Assessment in Chemistry Programs: Evolving Best Practices*, John Ryan and John Muffo (eds), Association for Institutional Research, Assessment in the Disciplines Series, Tallahassee: AIR, **2010** [assessment of curricular redesign and chemistry programs]

"A Placement Examination and Math Tutorial for General Chemistry," Norbert J. Pienta, *J. Chem. Educ.*, **2003**, *80*, pp 1244-7. [invited article for column on NSF sponsored innovation]

“A Web-Based, Calculator Skills Tutorial and Self-Test for General Chemistry Students,” N.J. Pienta, H.H. Thorp, R.M. Panoff, R.R. Gotwals, Jr., & H.P. Hirst, *Chemical Educator*, **2001**, *6* (5), 365-69.

UGA Chemistry

University of Georgia: ~35,000 students; ~26,000 undergrad

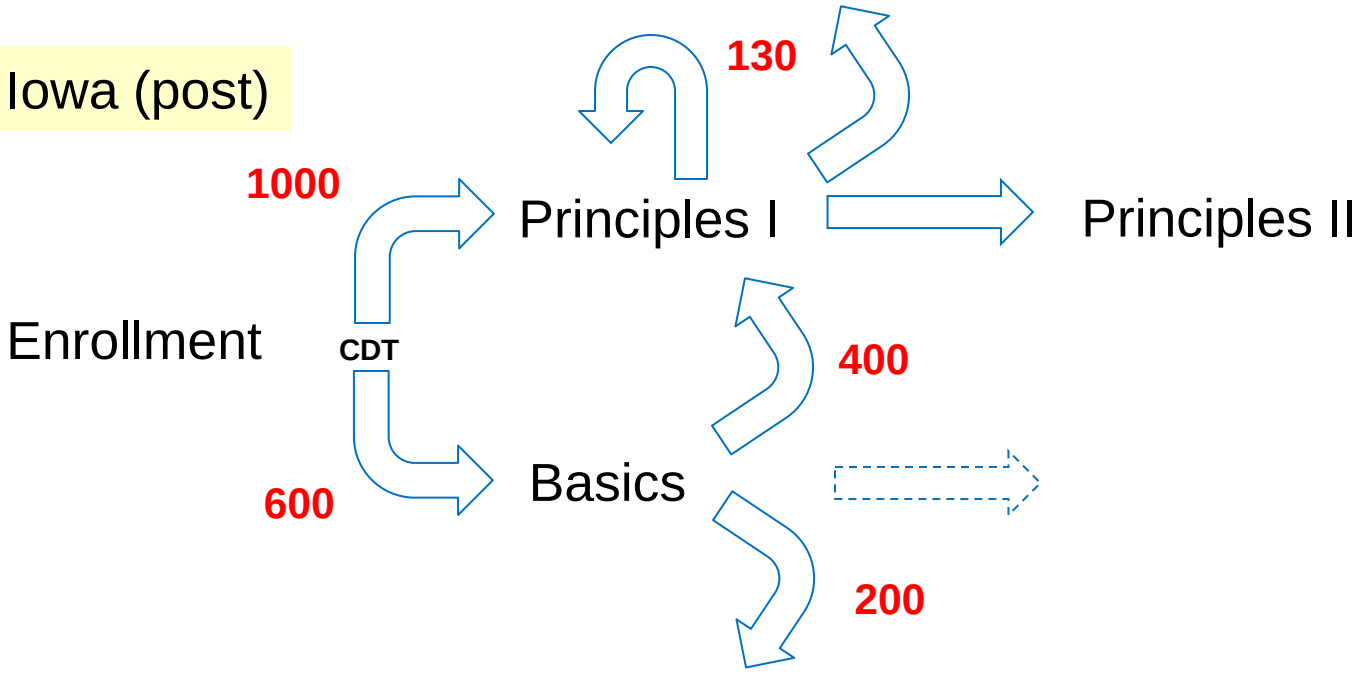
- Colleges: Ag & Environ Sci, Arts & Sciences, Business, Ecology, Education, Envir & Design, Family & Consumer Sci, Forest Res, Journalism & Mass Comm, Engineering
- Professional schools: Graduate School, Law, Pharmacy, Public Health, Public & Internat'l Affairs, Social Work, Veterinary Med, Medicine

First Year Students in Chemistry

- Principles of Chemistry: Withdrawal rate ~20-25%
- Basics of Chemistry (preparatory chemistry)
  - first offered fall 2014
  - diagnostic test = Iowa Diagnostic Test

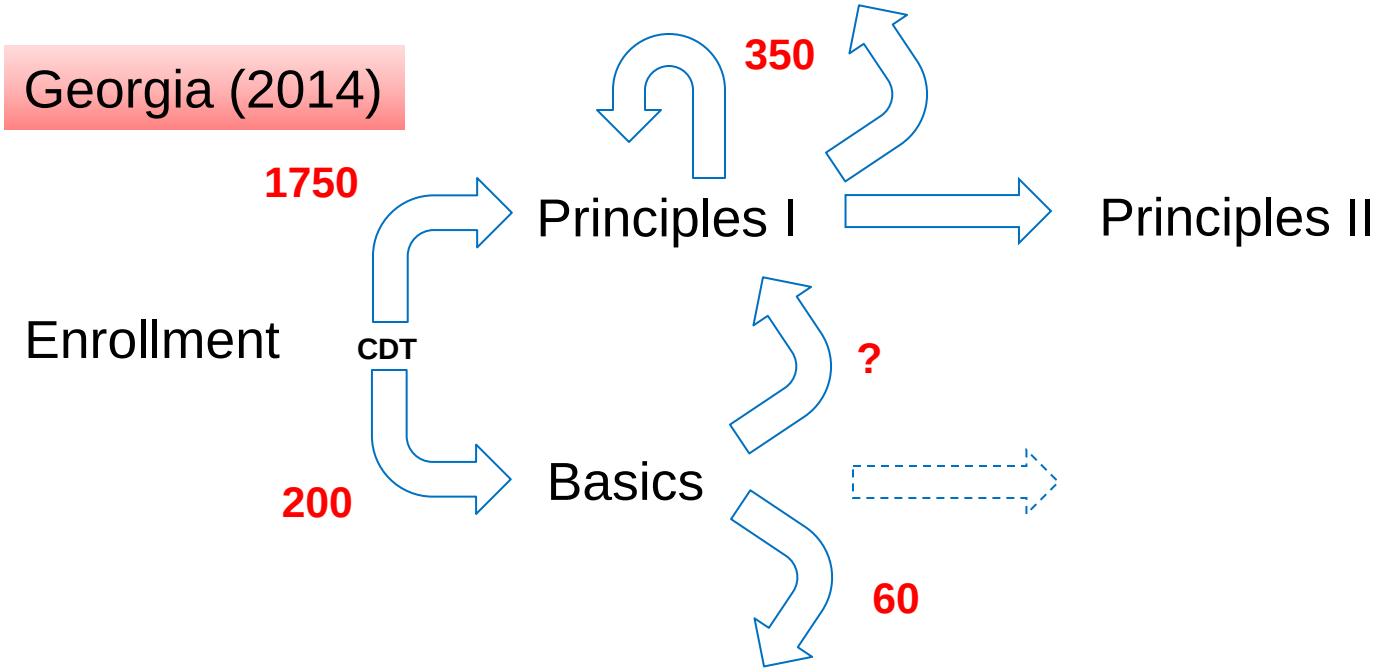
Redesign: lessons learned…

Iowa (post)



Redesign: lessons learned…

Georgia (2014)



Computer-based Testing

Systems:

- JExam: software and questions written by UGA faculty, ca. 1995-2013, server & security issues
- WebAssign: commercial (from Physics at NCSU), scripts and questions by UGA faculty
  - variety of question formats
  - regular updates, tech support

Hour Exams:

- computer lab with 67 seats, proctors, lockdown browser, students make appointments for 90 minute session
- formats (includes question parts, partial credit)
  - 35 minute, 10 question
  - 75 minute, 20 question [~8 sessions/day, 4 days for 1750 students]

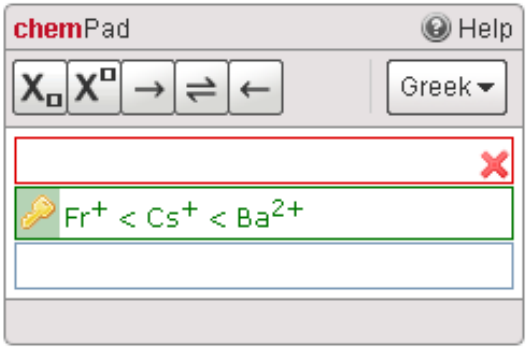
Question Formats

A balloon is filled to a certain volume at 653. torr and 23.1°C. If the temperature is doubled to 46.2°C, what pressure, in atmospheres, must be exerted on the balloon so that its volume doesn't change?

0.926 atm

Place these metal cations in order from least exothermic to most exothermic heat of hydration. *Be sure to separate the ions with less than symbols (<).*

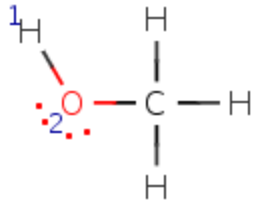
Cs^+; Ba^{2+}; Fr^+



Question Formats (cont'd)

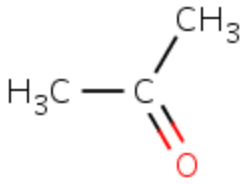
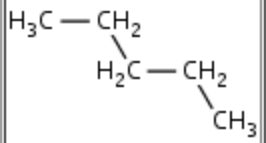
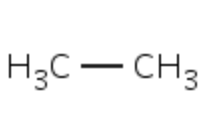
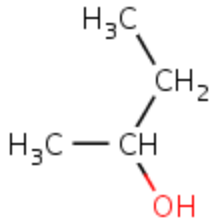
Draw the Lewis structure for molecules (a), (b), and (c) below and determine if they can form hydrogen bonds. Mark each hydrogen on the Lewis structures that can participate in hydrogen bonding with the label "M1". Also, mark non-hydrogen atoms that could participate in hydrogen bonding with another molecule with the label "M2". (Assign lone pairs and radical electrons where appropriate. Use the built-in Atom Map function to mark the appropriate atoms with the labels "M1" and "M2", respectively.)

MarvinSketch



Open MarvinSketch

Place the following compounds in order of *increasing* boiling point.

propanone	pentane	ethane	2-butanol
			

Lowest - ethane

- pentane

- propanone

Highes - 2-butanol

Question Strategies

Hour Exams:

- programming script (PERL); use of arrays; use of question pools
- challenges
  - make version equitable
  - prevent collusion

Homework / Self-asssessment:

- serves to familiarize students with interface; has value as assignment
- pre-lecture assignments: no time limit, 3 attempts, 1 before each lecture
- progress checks: limited time, 1 attempt, once per week

A Word about Blended Learning

Iowa course redesign [2002 → present]

- electronic homework [replace TA grading; active learning version of solved problems covered in class
- math and chemistry review [e-tutorials and exercises]
- 2 lab sessions → 1 case study + 1 lab [in-class activities; virtual tutorials and simulations]

Georgia course redesign [starts Spring 2014]

- Electronic system: assessment (tests & quizzes), self-assessment (homework, diagnostics), content (e-book, animations, simulations)
- Prep chem course [offer online version]

Acknowledgements

Course Redesign (Dept. of Chemistry)

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e-Homework (Chemistry at Iowa)

Ed Gillan, Peter Hansen, Len McGillivray, Darrell Eyman, Russell Larsen, Sonya Franklin, Chris Cheatum

$$$

(Basic Skills) = NSF DUE CCLI 00-88072

(Redesign) = Pew Program in Course Redesign (NCAT)

(Nano UG Education) = NSF NUE 04-07162

(Representations: Lewis structures) = NSF DUE CCLI 01-26050

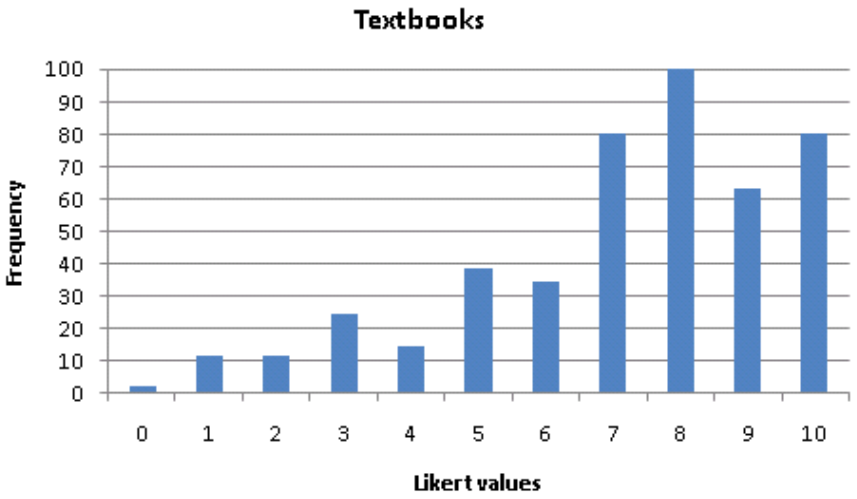
(Cognitive Load Theory) = NSF DUE CCLI 06-18600

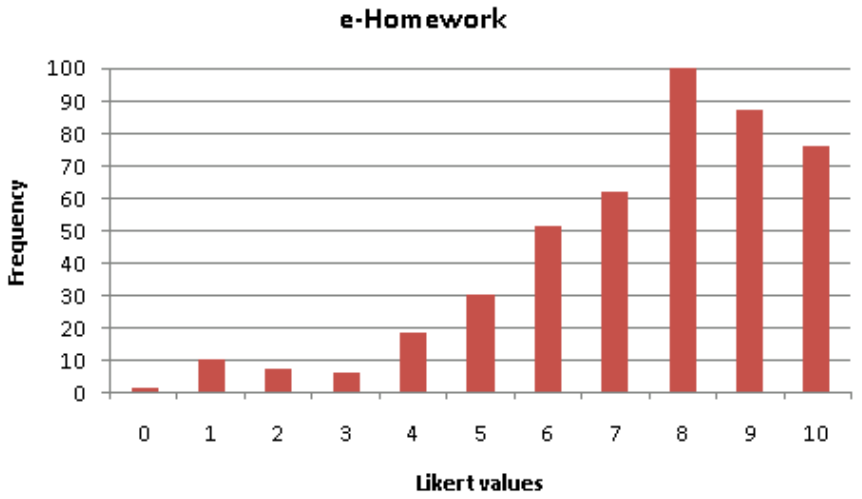
(Problem Solving) = NSF DUE TUES 09-

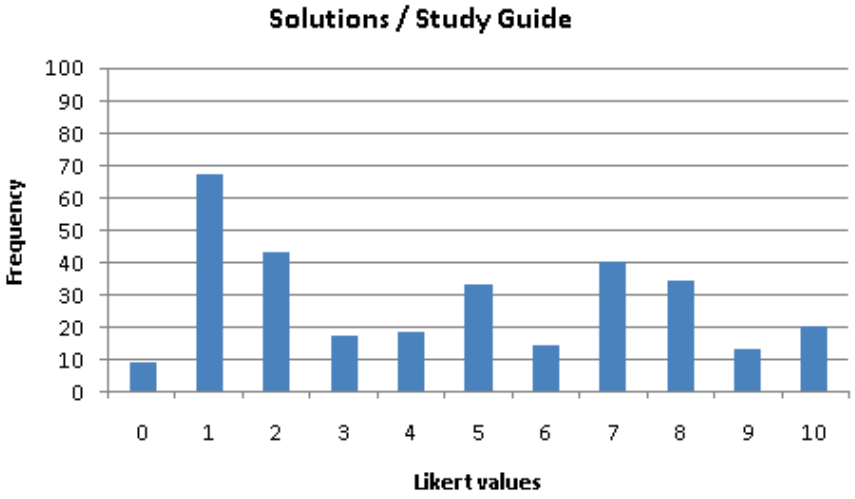
UGA Offices of VP for Research & VP for Instruction

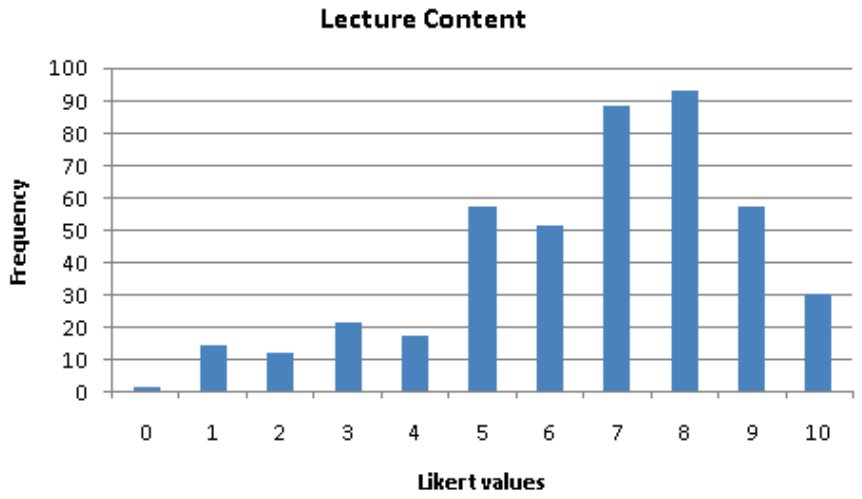
Frequencies

same y scale









What helped you learn and succeed?

1= least; 10 = most	*Fall 1999*	*Fall 2000*	*Fall 2002*	*Fall 2005*	*Fall 2009*
textbook	7.7	8.1	7.7	7.3	7.2
solns/study guide	6.8	7.4	7.0	6.6	4.5
CD-ROM w/ text	4.0	2.5	2.4	1.6	1.6
text website	---	---	2.7	2.5	3.3
lecture content	5.6	6.5	6.6	7.4	6.7
interesting	4.5	5.0	6.4	6.5	6.0
relevant	5.7	6.3	6.6	7.0	6.5
course website	---	---	6.5	5.9	6.3
EOC problems	---	---	7.1	6.4	5.7
written homework	6.6	5.4	---	---	---
electronic homework	4.1	3.6	7.6	7.0	7.5
discussion session	5.9	4.3	5.2	6.0	6.8
case study session	---	---	4.9	5.8	6.4
laboratory session	---	---	4.5	5.3	5.9
TA office hours	4.1	3.4	3.0	4.8	5.4
study group	5.9	4.3	4.7	5.0	6.0
paid tutor	3.5	2.4	1.9	4.3	2.7
friends	6.8	6.3	6.1	7.0	6.8

Chang
Chang
BLB
Silberberg
BLB
CSB
CSUF
CSB (M-H)
WebAssign
WebAssign

redesign implemented