What is Blended Learning and Flipped Classroom?

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Caveat

"evidence shows that it is not the technology per se *that changes learning and teaching but the pedagogical advantage we make of its use"*

Price and Kirkwood (2008)

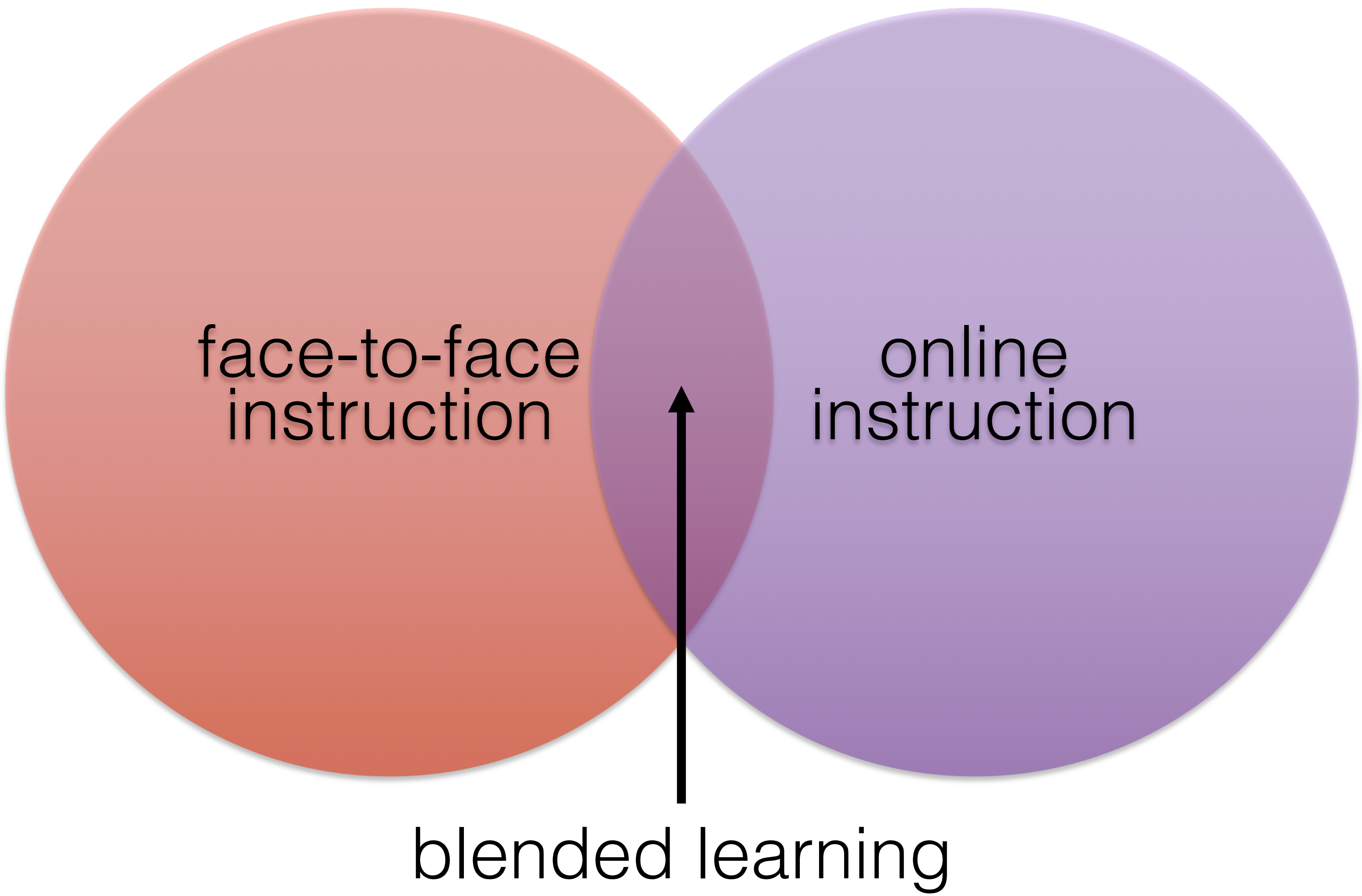
Price, L., and A. Kirkwood (2008) *Technology in the United Kingdom's higher education context*. In S. Scott & K. Dixon (Eds.), *The 21st Century, Globalised University: Trends and Development in Teaching and Learning* (pp. 83–113). Perth: Black Swan.

Blended Learning is…

“a combination of on-site (i.e. face-to-face) with online experiences to produce effective, efficient and flexible learning”

Stein and Graham (2016)

Stein, J., and C. R. Graham (2014) *Essentials for blended learning: A standards-based guide*. New York: Routledge.



Stein, J., and C. R. Graham (2014) *Essentials for blended learning: A standards-based guide*. New York: Routledge.

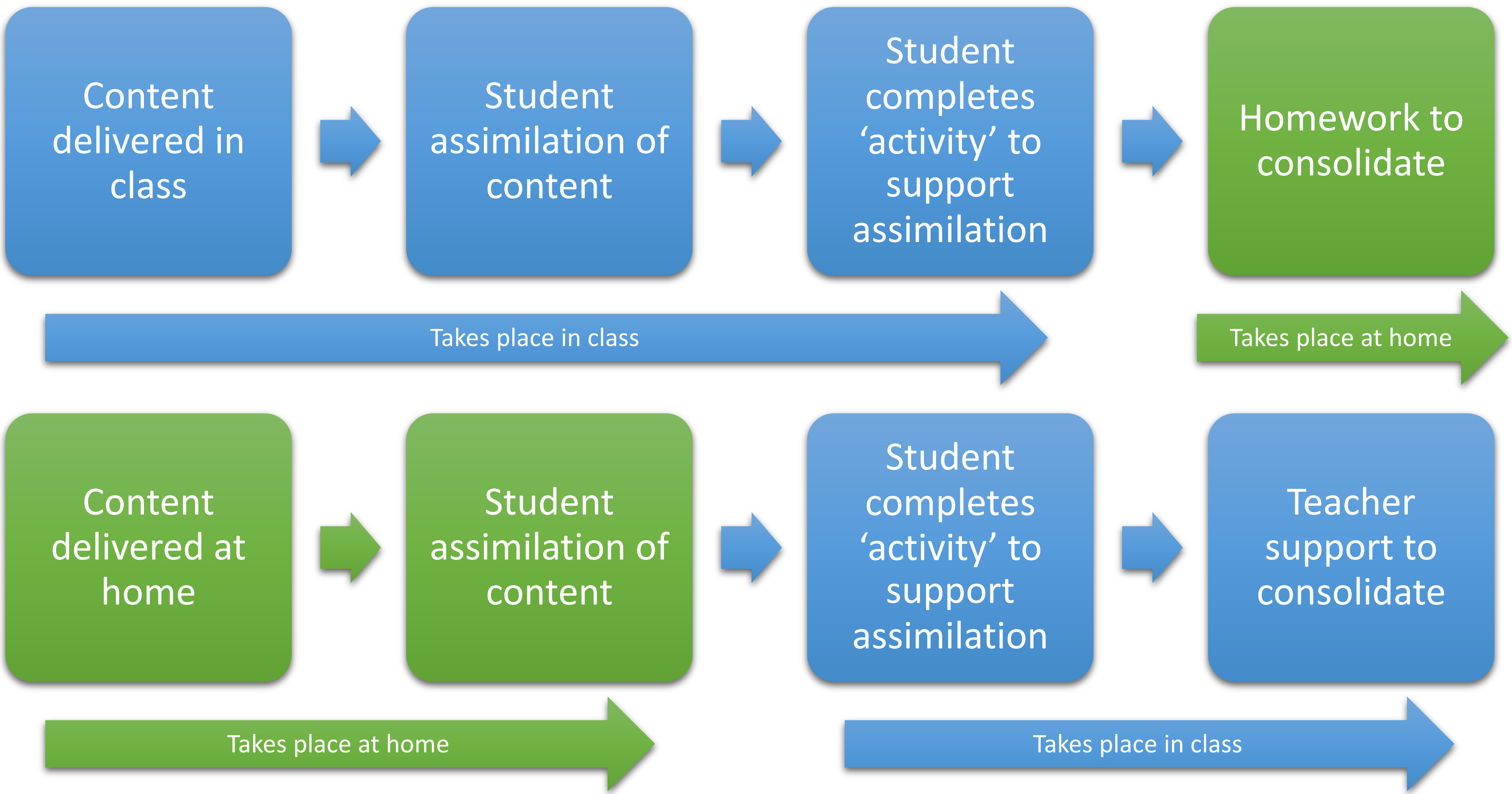
Why Blended Learning?

1. Improved instructional design
2. Increased guidance and triggers
3. Easier access to learning activities
4. Individualised learning opportunities
5. Increased engagement through social interaction
6. Time on task

Stein, J., and C. R. Graham (2014) *Essentials for blended learning: A standards-based guide*. New York: Routledge.

The Flipped Classroom Approach

Traditional *vs* Flipped



Based on a graphic taken from Steed, A. (2012) The Flipped Classroom, *Teaching Business & Economics*, **16**, 9–11.

Traditional *vs* Flipped

Traditional:
Lessons in class, homework at home

Flipped:
Lessons at home, homework in class

Theoretical Basis

"To develop competence in an area of inquiry, students must: a) have a deep foundation of factual knowledge, b) understand facts and ideas in the context of a conceptual framework, and c) organize knowledge in ways that facilitate retrieval and application"

Bransford *et al.* (2000, p. 16)

Bransford, J. D., A. L. Brown and R. R. Cocking (2000) *How people learn: Brain, mind, experience, and school*. Washington, D.C.: National Academy Press.

Theoretical Basis

"A 'metacognitive' approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them"

Bransford *et al.* (2000, p. 18)

Bransford, J. D., A. L. Brown and R. R. Cocking (2000) *How people learn: Brain, mind, experience, and school*. Washington, D.C.: National Academy Press.

Activity (20 mins)

Read the description of the key elements of flipped classroom and select one or more flipped classroom examples to review. Consider the following questions and discuss what you discover in your group.

1. How do students gain first exposure prior to class?
2. Is there an incentive for students to prepare for class?
3. What mechanism is present to assess student understanding?
4. What kind of in-class activities has the lecturer introduced?
5. What potential pitfalls has the lecturer identified?
6. What went well?

What are the key elements?

1. Provide an opportunity for students to gain first exposure prior to class;
2. Provide an incentive for students to prepare for class;
3. Provide a mechanism to assess student understanding; and,
4. Provide in-class activities that focus on higher level cognitive activities.

Brame, C., (2013) *Flipping the classroom*, Vanderbilt University Center for Teaching [Retrieved 12 February 2015 from http://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/].

A Flipped Classroom Exemplar

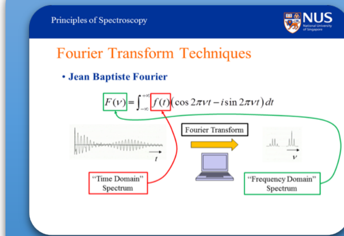
Week before class

One day before class

In class

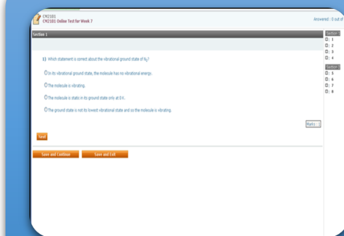
Following week

Online Lectures



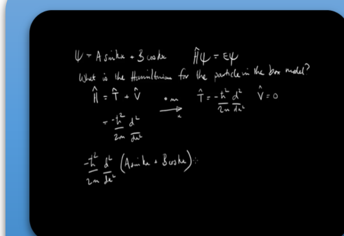
- Playlists of short (10–15 minute), narrated presentations

Weekly Online Quizzes



- Identification of student misconceptions

Large Class Review Session



- Review of online material
- Learner response system

Small Group Active Learning

- Work in groups of 3–5 students
- Active problem solving
- Peer learning

Example Important Pedagogical Components

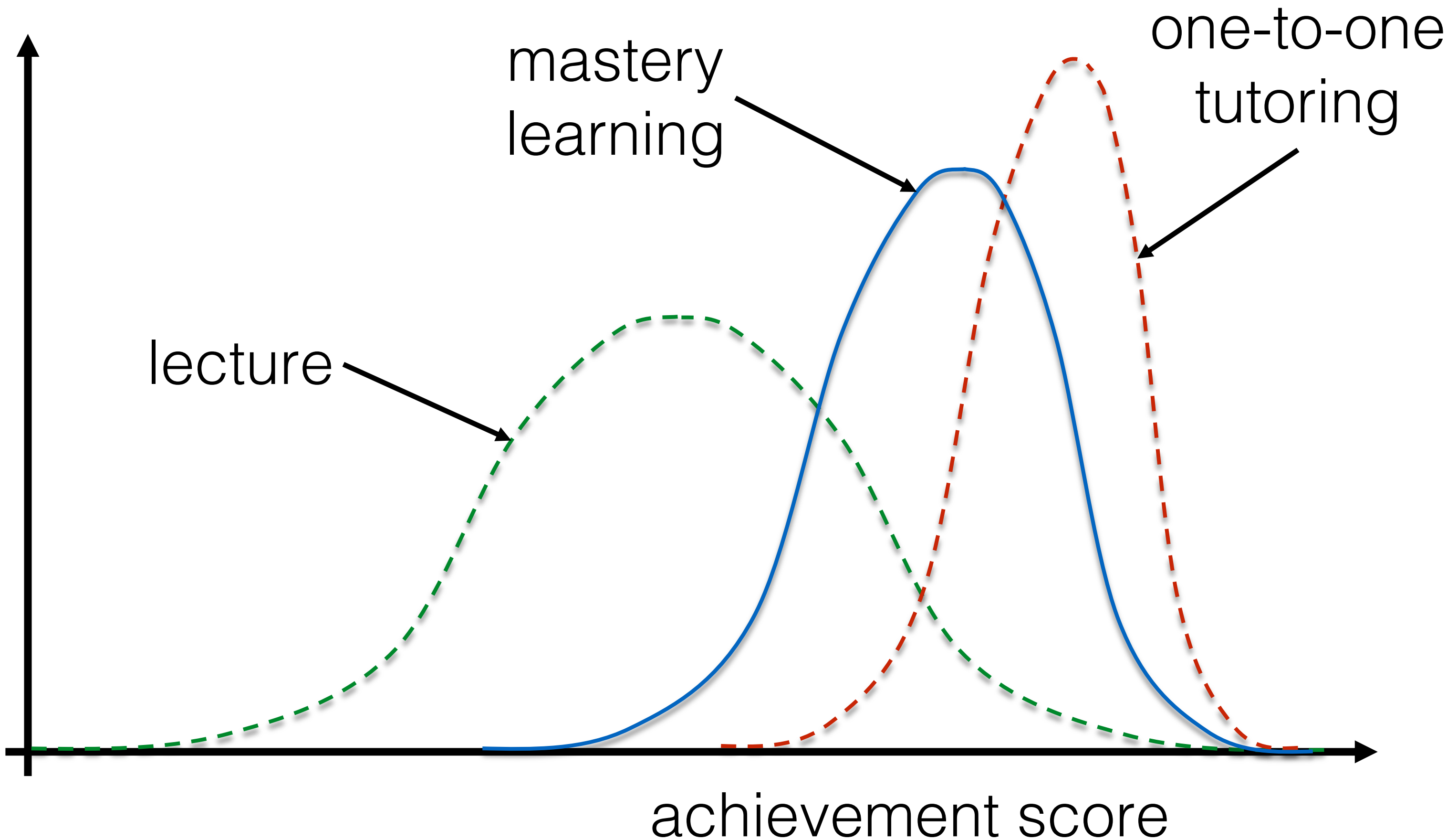
Just-in-Time Teaching

"The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly."

Ausubel (1968)

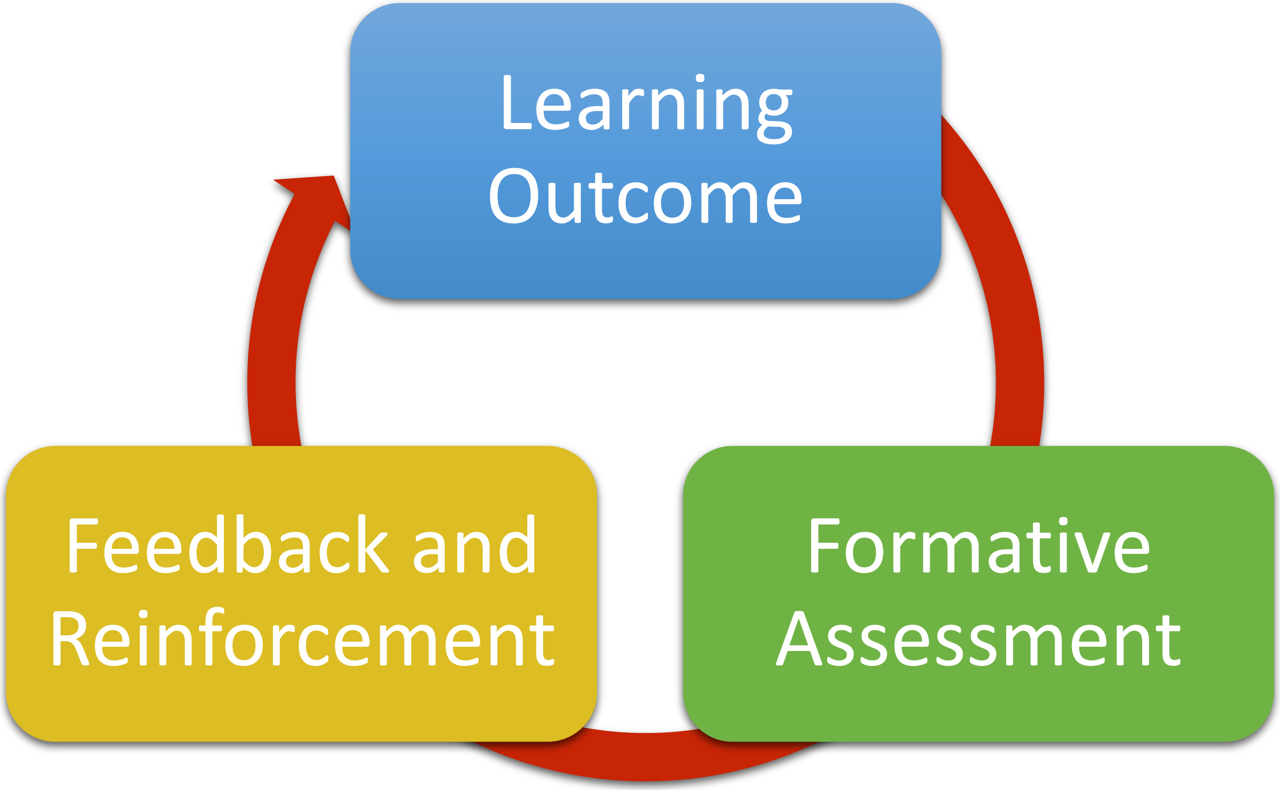
Novak, G. N., E. T. Patterson, A. Gavrin, and W. Christian (1999) *Just-in-Time Teaching: Blending Active Learning and Web Technology*, Saddle River: Prentice Hall.
Ausubel, D. P. (1968) *Educational Psychology: A Cognitive View*, New York: Rinehart and Winston, Inc.

Mastery Learning



Bloom, B. (1984) The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring, *Educational Researcher*, 13(6), 4–16.

Mastery Learning



Bloom, B. S., and J. B. Carroll. (1971) *Mastery learning: Theory and practice*, New York: Holt, Rinehart and Winston.

Weekly Online Quiz

CM2101
Online Quiz: Topic 4a

CLOSE

Objectives and Instructions

This is a mastery quiz. However, you will have only **5 attempts** to complete this assessment before the deadline.

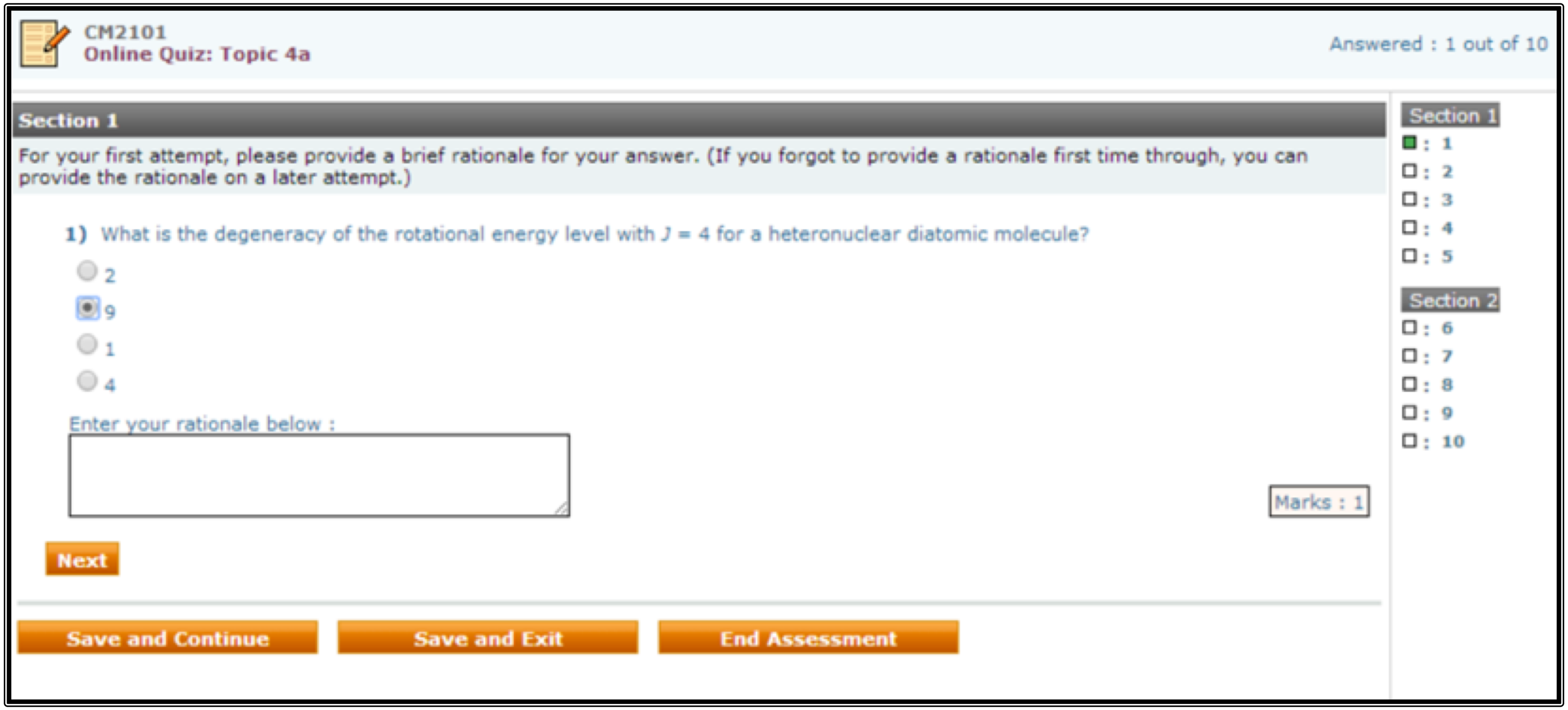
Section 1 requires a rationale on your first attempt.

An Assessment attempt is considered as "incomplete" if you do not click on the **End Assessment** button. This Assessment allows you to resume the **latest** "incomplete" attempt at any time within the Assessment's opening and expiry date.

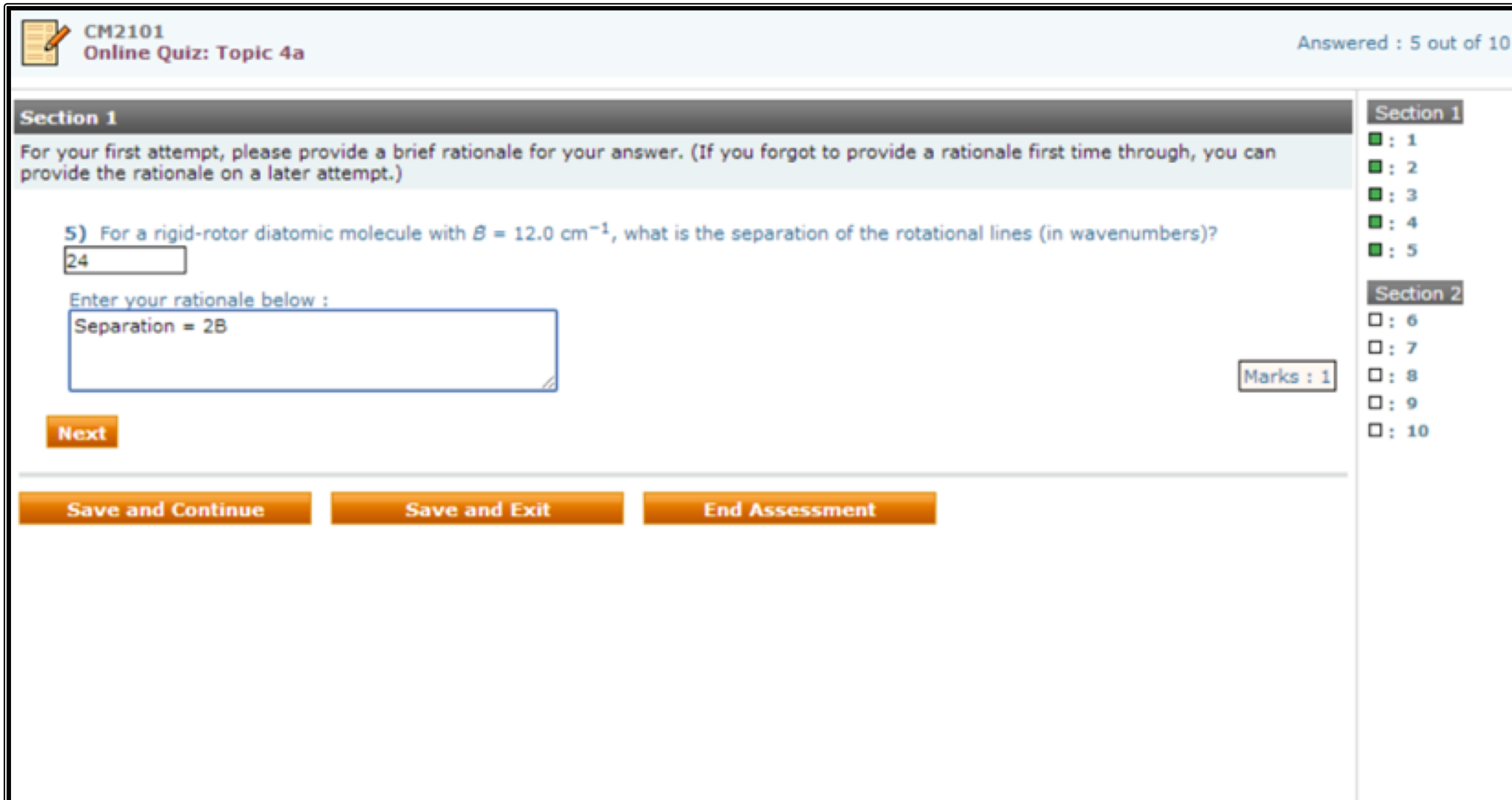
Module Code :	CM2101
Assessment Owner :	ADRIAN MICHAEL LEE
Opening Date :	03-Feb-2014 12:00 AM
Expiry Date :	07-Feb-2014 11:59 PM
Student :	ADRIAN MICHAEL LEE
Time Limit :	**No time limit**
Number of Attempts :	Complete Attempts : **0** Incomplete Attempts : **0** Allowed Attempts : 5

Read all instructions before taking the Assessment, click **Start** to begin.

Weekly Online Quiz



Weekly Online Quiz



Weekly Online Quiz

CM2101
Online Quiz: Topic 4a

CLOSE

Print

Assessment Title :	Online Quiz: Topic 4a	**Number of Attempts :**	1 out of 5
Student Name :	ADRIAN MICHAEL LEE	**Duration :**	6m 50s
Start Date and Time :	09-Apr-2014 09:57 AM	**Total Marks :**	5 out of 10
	You can always view your assessment feedback by clicking on Usage/My Usage in the horizontal menu from the IVLE Workspace.		

Section 1

For your first attempt, please provide a brief rationale for your answer. (If you forgot to provide a rationale first time through, you can provide the rationale on a later attempt.)

1) What is the degeneracy of the rotational energy level with $J = 4$ for a heteronuclear diatomic molecule?

- 2
- 9
- 1
- 4

Your Answer :	9
Solution :	Degeneracy arises from the fact that the different spatial orientations have the sam energy. For a given value of J, there are a number of possible M_J values.
Your Marks :	1 out of 1

Peer Instruction

EDUCATION

Farewell, Lecture?

Eric Mazur

A physics professor describes his evolution from lecturing to dynamically engaging students during class and improving how they learn.

Discussions of education are generally predicated on the assumption that we know what education is. I hope to convince you otherwise by recounting some of my own experiences. When I started teaching introductory physics to undergraduates at Harvard University, I never asked myself how I would educate my students. I did what my teachers had done—I lectured. I thought that was how one learns. Look around anywhere in the world and you'll find lecture halls filled with students and, at the front, an instructor. This approach to education has not changed since before the Renaissance and the birth of scientific inquiry. Early in my career I received the first hints that something was wrong with teaching in this manner, but I had ignored it. Sometimes it's hard to face reality.

When I started teaching, I prepared lecture notes and then taught from them. Because my lectures deviated from the textbook, I provided students with copies of these lecture notes. The infuriating result was that on my end-of-semester evaluations—which were quite good otherwise—a number of students complained that I was "lecturing straight from (his) lecture notes." What was I supposed to do? Develop a set of lecture notes different from the ones I handed out? I decided to ignore the students' complaints.

Click here. Students continually discuss concepts among themselves and with the instructor during class. Discussions are spurred by multiple-choice conceptual questions that students answer using a clicker device. See supporting online text for examples of such "clicker questions."

A few years later, I discovered that the students were right. My lecturing was ineffective, despite the high evaluations. Early on in the physics curriculum—in week 2 of a typical introductory physics course—the Laws of Newton are presented. Every student in such a course can recite Newton's third law of motion, which states that the force of object A on object B in an interaction between two objects is equal in magnitude to the force of B on A—it sometimes is known as "action is reaction." One day, when the course had progressed to more complicated material, I decided to test my students' understanding of this concept not by doing traditional problems, but by asking them a set of basic conceptual questions (*1*, *2*). One of the questions, for example, requires students to compare the forces that a heavy truck and a light car exert on one another when they collide. I expected that the students would have no trouble tackling such questions, but much to my surprise, hardly a minute after the test began, one student asked, "How should I answer these questions? According to what you taught me or according to the way I usually think about these things?" To my dismay, students had great difficulty with the conceptual questions. That was when it began to dawn on me that something was amiss.

In hindsight, the reason for my students' poor performance is simple. The traditional approach to teaching reduces education to a transfer of information. Before the industrial revolution, when books were not yet mass commodities, the lecture method was the only way to transfer information from one generation to the next. However, education is so

CREDIT: (BOTTOM) JON CHASE/HARVARD UNIVERSITY

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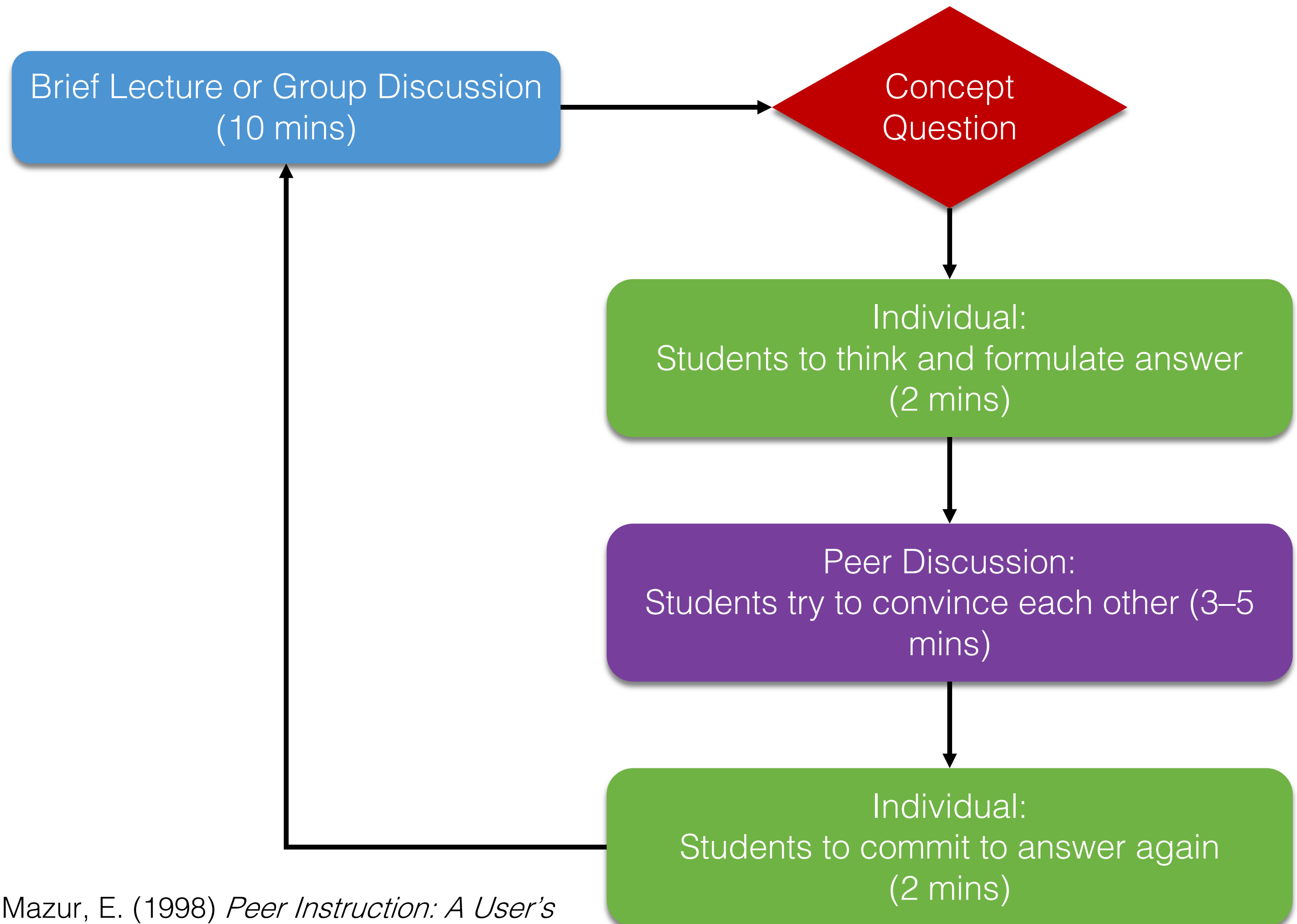
Mazur, E. (2009) Farewell, Lecture?, *Science*, **323**, 50–51.

Peer Instruction



Mazur, E. (1998) *Peer Instruction: A User's Manual*, Englewood Cliffs: Prentice Hall.

Three Social Science Generalisations

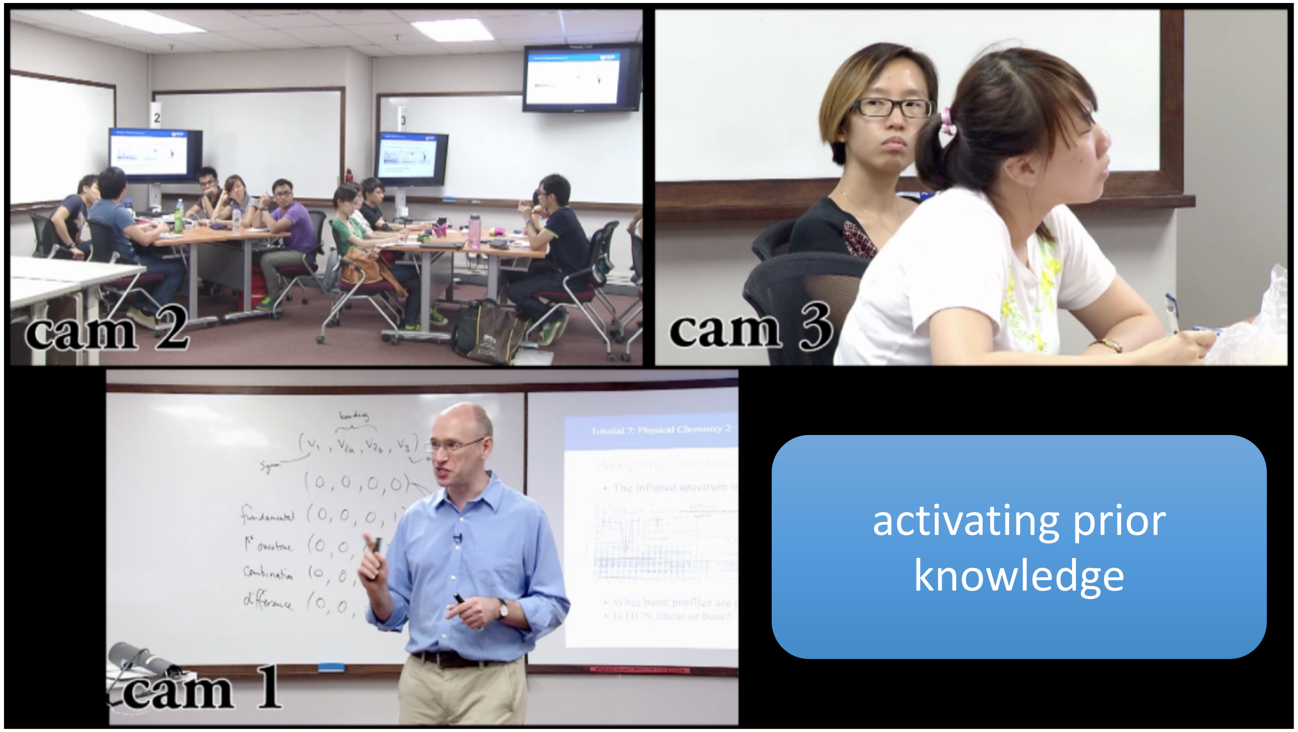
1. Social connections motivate

2. Teaching teaches the teacher

3. Instant feedback improves learning

King, G., and M. Sen (2013) How social science research can improve teaching, *PS: Political Science and Politics*, **46**, 621–629.

Active Learning Tutorial: Activating prior knowledge

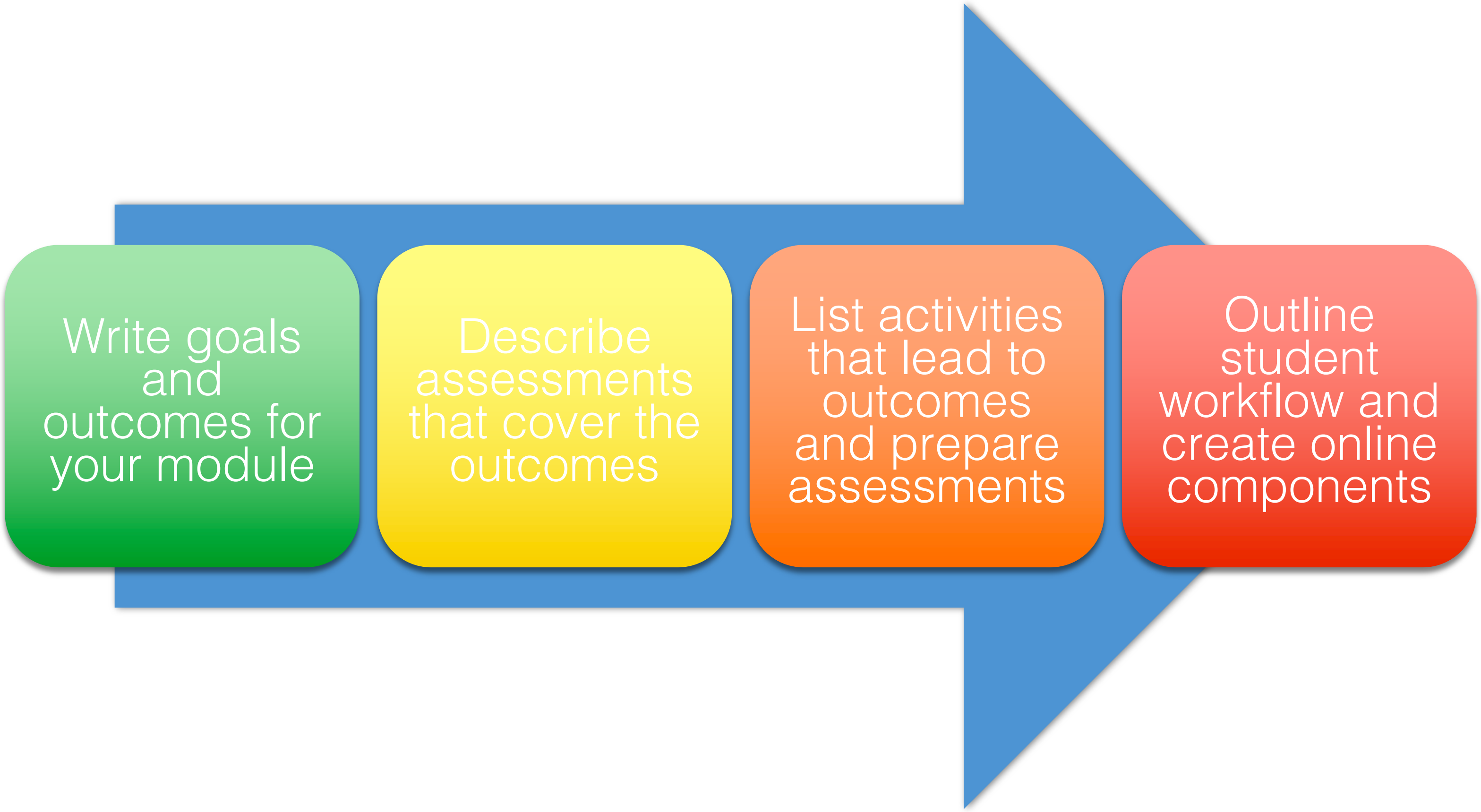


Active Learning Tutorial: Peer learning

Active Learning Tutorial: Facilitation

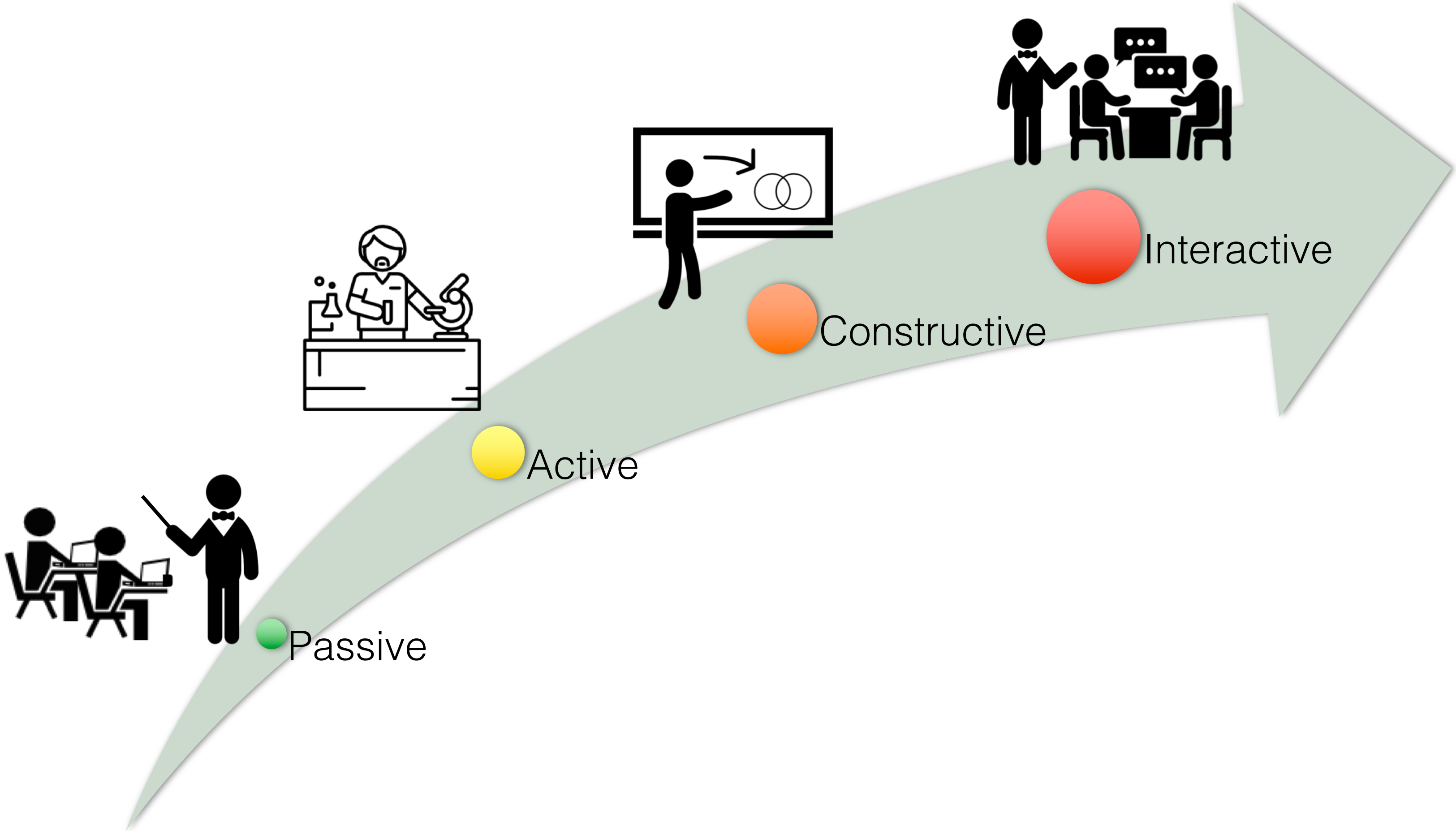
How to Design a Blended Learning Experience

The Design Process



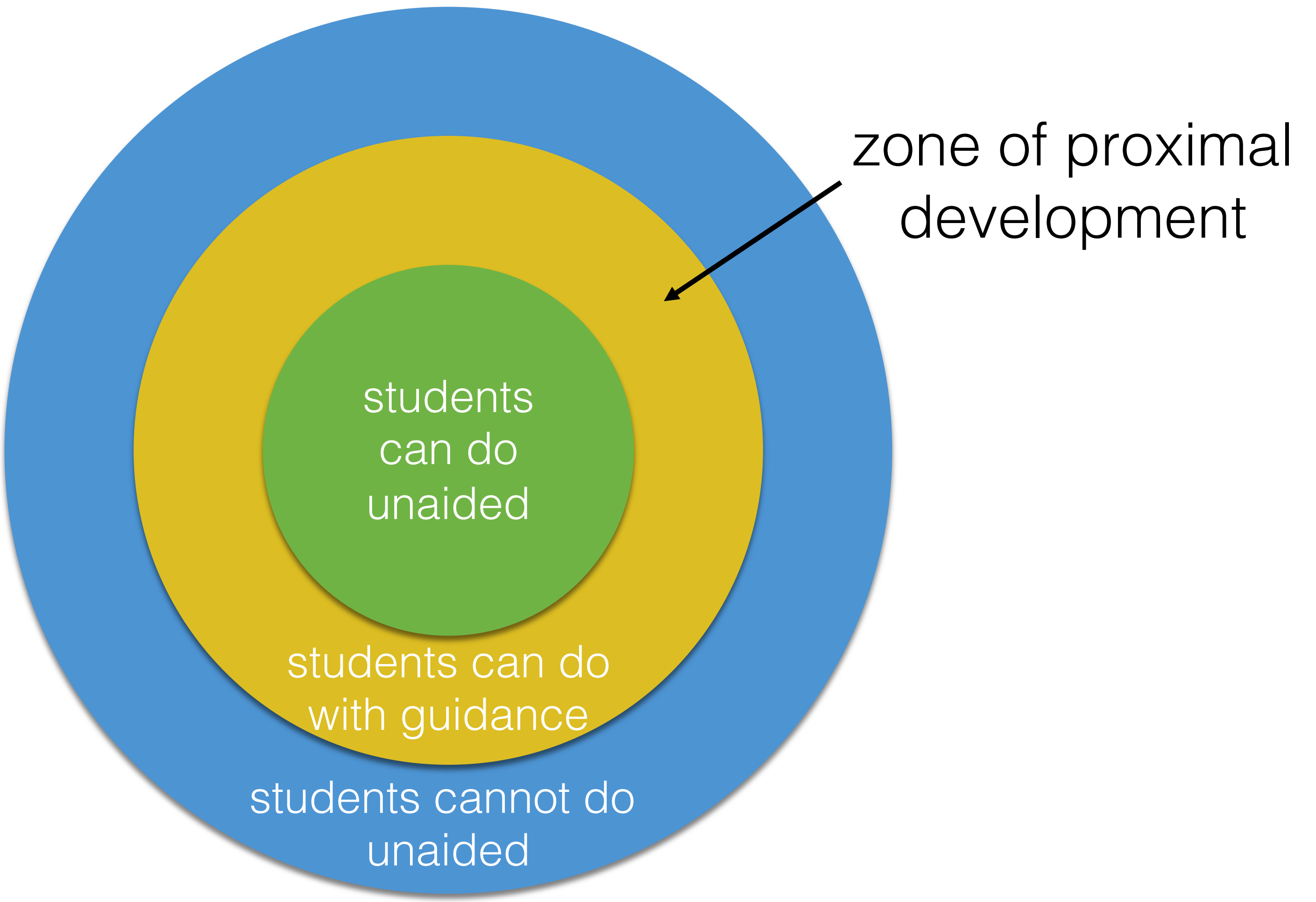
Wiggins, G. P., and J. McTighe. (2005). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

Designing Learning Activities



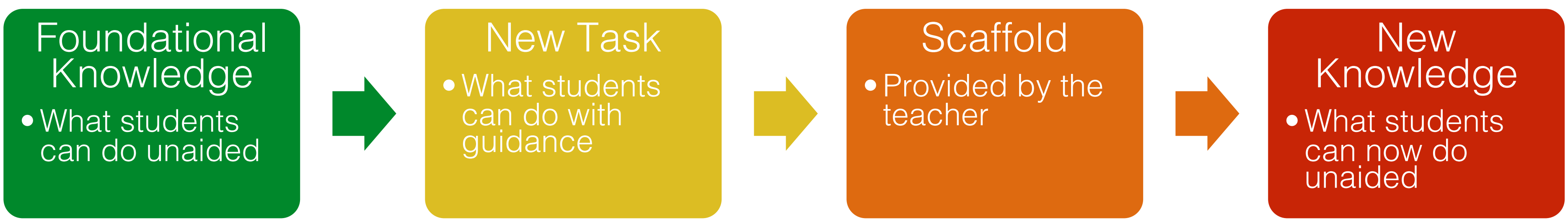
Mirriahi, N., D. Alonzo and B. Fox. (2015) A blended learning framework for curriculum design and professional development, *Research In Learning Technology*, **23:** doi:http://dx.doi.org/10.3402/rlt.v23.28451.

Zone of Proximal Development



Vygotsky, L. S. (1978) *Mind in Society: Development of Higher Psychological Processes*, Harvard University Press, 86–87.

Model of Instructional Scaffolding



Wood, D., J. S. Bruner, and G. Ross (1976) The role of tutoring in problem solving, *Journal of Psychology and Psychiatry*, **17**, 89–100.

Intended Learning Outcome

On the completion of the module, students should be able to:

1. *Describe* the basic spectroscopic concepts that control the intensity and width of a spectral line.
2. *Apply* quantum-mechanical and group-theoretical principles to a variety of different spectroscopic systems.
3. *Plan*, *organise*, *monitor* and *evaluate* learning to become an effective self-regulating and reflective learner.
4. *Analyse* spectroscopic data to determine physical parameters that characterise small molecules.
5. *Predict* the spectral features that would arise depending on the structure of a small molecule.

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Using Flipped Classroom to Scaffold ILO

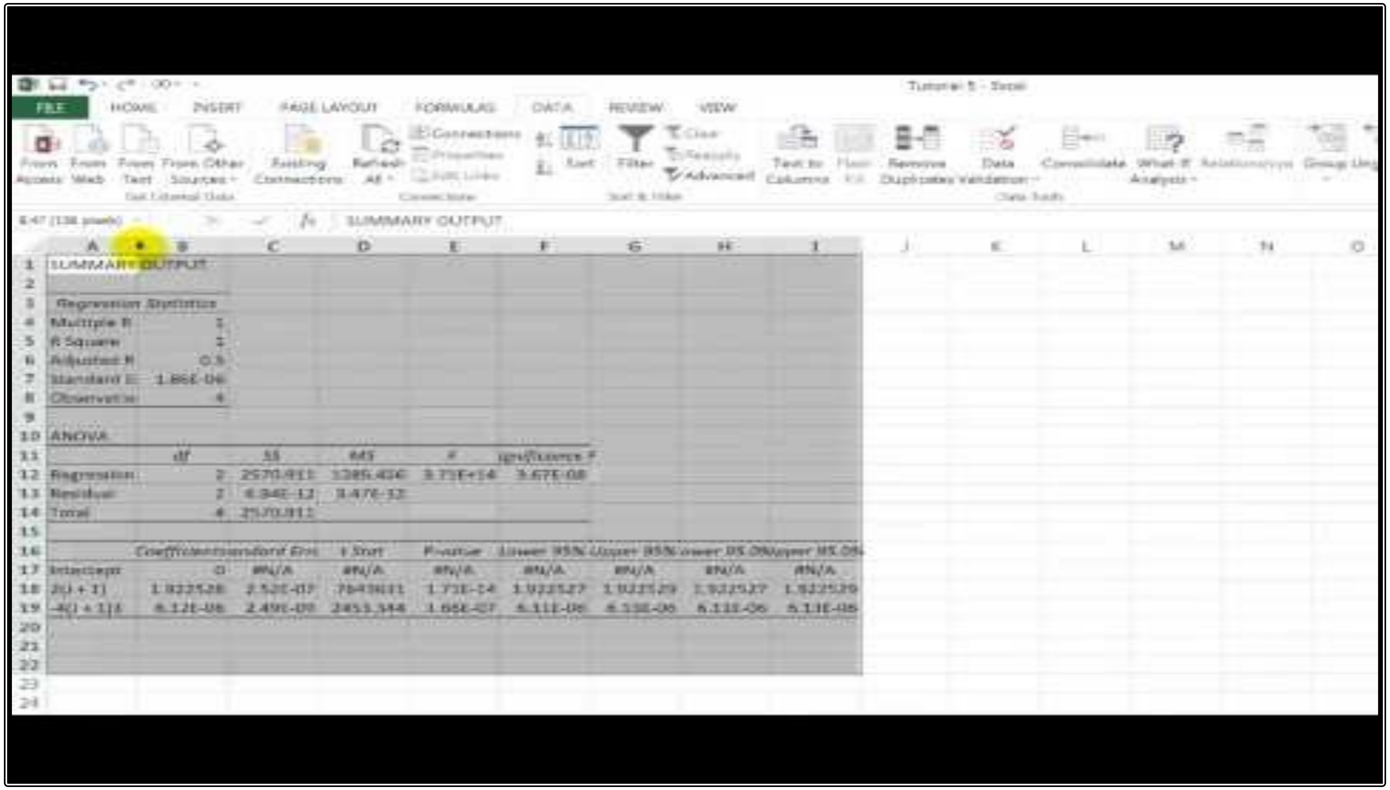
4. *Analyse* spectroscopic data to determine physical parameters that characterise small molecules.

Challenge: Traditional teaching does not authentically teach or assess real-world spectroscopic data analysis

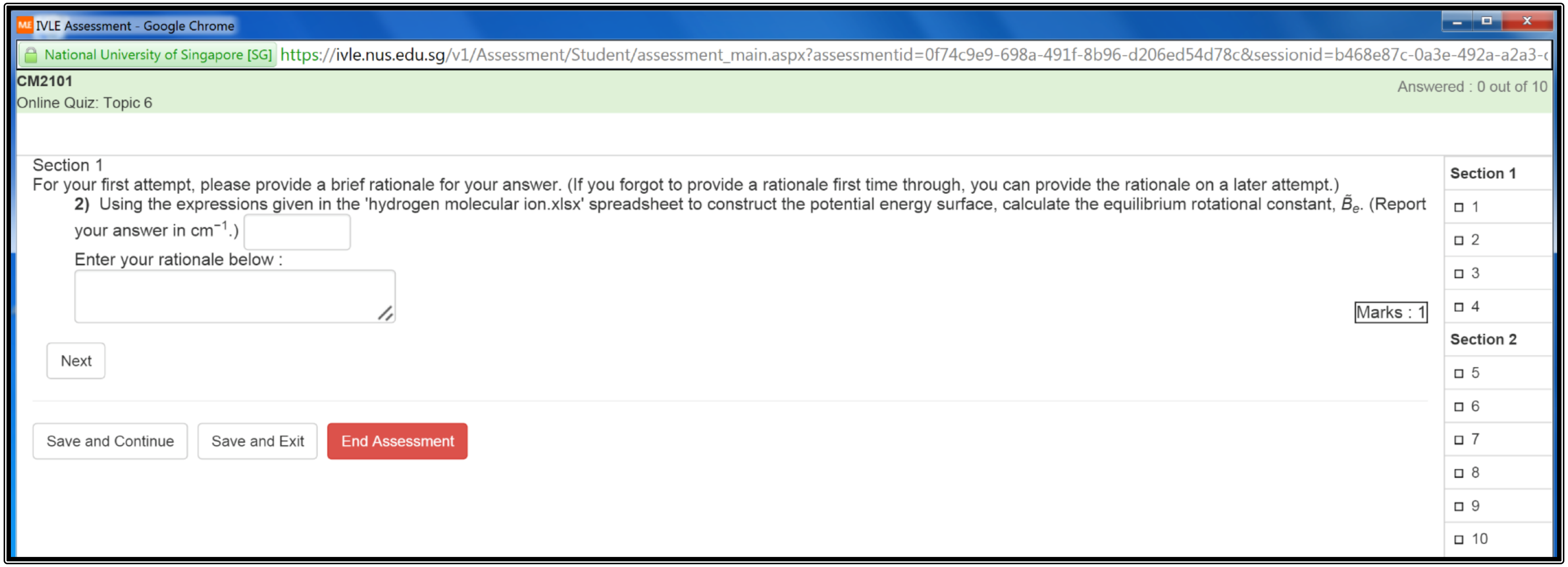
Students need to be able to use technology, such as Excel, to do linear regression

Online Introduction to Excel

- Integrate the use of Excel throughout the module



Integrated into Weekly Quizzing



Use in Active Learning Tutorials

Tutorial 4 (solution) - Excel

	A	B	D	E	F	G	H	I	J
1	***h***	6.62608E-34	***J***	***J* + 1**	**y_i (MHz)**	**y_i**	**calculated**	**2(*J* + 1)**	**-4(*J* + 1)^3**
2	***c***	2.99793E+08	0	1	11865.712	0.395797417		2	-4
3	***u***	1.66054E-27	1	2	23731.302	0.791590764		4	-32
4	$\tilde{B}$	0.197898107	2	3	35596.91	1.187384712		6	-108
5	$\tilde{D}$	4.23346E-08	3	4	47462.4	1.583174723		8	-256
6			4	5	59327.745	1.978959898		10	-500
7			5	6	71192.959	2.374740703		12	-864
8			6	7	83057.99	2.770515404		14	-1372
9			7	8	94922.81	3.166283067		16	-2048
10			8	9	106787.38	3.562042391		18	-2916
11			9	10	118651.68	3.957792708		20	-4000
12			10	11	130515.68	4.353533019		22	-5324
13			11	12	142379.34	4.749261988		24	-6912
14			12	13	154242.63	5.144978616		26	-8788
15			13	14	166105.53	5.540682234		28	-10976
16			14	15	177968	5.936371509		30	-13500
17			15	16	189830.02	6.332045774		32	-16384
18			16	17	201691.55	6.727703694		34	-19652
19			17	18	213552.56	7.123344269		36	-23328
20			18	19	225413.02	7.518966498		38	-27436
21			19	20	237272.91	7.914569714		40	-32000
22			20	21	249132.18	8.310152249		42	-37044
23			21	22	260990.82	8.705713769		44	-42592
24			22	23	272848.78	9.101252607		46	-48668
25			23	24	284706.04	9.496768095		48	-55296
26			24	25	296562.58	9.892259567		50	-62500

Sheet4 | OCS-32 spectrum | Sheet6 | **OCS-34 spectrum** | OCS bond lengths

Align Assessment

- Individualized homework assignments

1. Linear regression (easy)
2. Erroneous example
3. Linear regression (hard)

For Homework Assignment 1, you need to determine R_∞, the Rydberg constant. In the table below, you are being provided with 5 spectral lines from a hydrogen-like ion.[1] For this system, the following theoretical model accurately models the energy levels:

$$E_n = -Z^2 . R_\infty . \frac{1}{n^2},$$

where Z represents the charge on the nucleus, and n represents the principal quantum number. This formula can be used to determine the Rydberg-like formula for this system that models the frequencies of the 5 spectral lines.

In order to determine the magnitude of the Rydberg constant, you will need to determine the initial and final quantum states for the transitions associated with the spectral features in the emission spectrum. You may assume that the final quantum state, n_f, is the same for each transition, and that the 5 initial quantum states are adjacent. (This is the same set of assumptions used in Tutorial 1.) Your approach to determining the initial and final quantum states can follow that employed in Tutorial 1. I have placed an Excel template for this assignment in the Workbin to aid in this determination. The first worksheet in this template is set up in a manner similar to that used in Tutorial 1. I suggest that you paste your 5 spectral frequencies into cells [J2:N2] in the *quantum numbers* worksheet.

Once you have determined the quantum states, you will need to determine Z and therefore the element with which your data is consistent. With this value of Z, you can determine the independent variable associated with the parameter, R_∞. The regression worksheet can be used to set up the dependent and independent variables so that you can employ linear regression to determine R_∞. Once you have determined the Rydberg constant you should use the uncertainty to report your value to the appropriate number of significant figures (the 'Error Propagtion.pdf' summarises the discussion concerning significant figures that was conducted during Tutorial 1). You will finally be asked to determine whether the theoretical value (found in cell B6 of the quantum numbers worksheet) is consistent with your value that you have derived from the observations.

Please report your answers to the appropriate level of significant figures in the 'Homework Assignment 1' survey found on IVLE. You have until **11.59pm Sunday 28 February 2016** to complete this assignment.

Your spectral data is as follows:

Spectral line	Frequency / cm^{-1}
1	780521.915
2	914682.067
3	995365.011
4	1048012.683
5	1083820.596

[1] A hydrogen-like ion is any atomic nucleus with one electron and thus is isoelectronic with hydrogen.

Align Assessment

- Individualized homework assignments

1. Linear regression (easy)
2. Erroneous example
3. Linear regression (hard)

On close examination of the microwave spectrum of the sample, it appears that two diatomic molecules are present that I have identified as molecules A and B. The microwave spectrometer was able to measure 10 spectral lines from around 20 cm^{-1} to 37 cm^{-1}. The data is given in the following table:

Spectral line	Frequency / cm^{-1}	Molecule Assignment	$J_{initial}$ Assignment
1	21.22755	A	6
2	23.31289	B	6
3	24.25665	A	7
4	26.63941	B	7
5	27.28438	A	8
6	29.96438	B	8
7	30.31058	A	9
8	33.28760	A	10
9	33.33507	B	9
10	36.35769	A	11

Linear regression was performed on the spectral data for the two molecules individually and the following parameters were determined.

For molecule A:

$\tilde{B} = 1.67404$ cm^{-1}
$\tilde{D} = 9.54876 \times 10^{-6}$ cm^{-1}

For molecule B:

$\tilde{B} = 1.66600$ cm^{-1}
$\tilde{D} = 8.10000 \times 10^{-6}$ cm^{-1}

These data can be used to derive the moments of inertia and the equilibrium vibrational frequencies using the following formulae:

$$I = \frac{h}{8\pi^2 \tilde{B} \tilde{c}} \text{ and } \tilde{\nu}_e = \sqrt{\frac{4\tilde{B}^3}{\tilde{D}}}$$

These formulae gave the following results.

For molecule A:

$I = 1.84533 \times 10^{-46}$ kg m^2
$\tilde{\nu}_e = 1401.86$ cm^{-1}

For molecule B:

$I = 1.68024 \times 10^{-44}$ kg m^2
$\tilde{\nu}_e = 1511.12$ cm^{-1}

Align Assessment

- Individualized homework assignments

1. Linear regression (easy)
2. Erroneous example
3. Linear regression (hard)

For Homework Assignment 3, you need to analyse an absorption rovibrational spectrum. Part of the dataset is the fundamental rovibrational band for which you are also given the intensity data. An updated Excel template for this assignment has been placed in the Workbin. In order to complete this assignment you need to enter the frequencies and intensities for each of the spectral lines into columns J and K of the spreadsheet (note that intensities are only required for the first 10 lines). This will automatically populate the graph showing the spectrum of the fundamental band. This should aid you in assigning the initial and final quantum numbers to each spectral line (columns F through I). You will then need to determine the independent variables associated with the **six** parameters and calculate the values for the **six** independent variables for each spectral line (columns L through Q). Note that the independent variables associated with B_2 have been set to zero for the lines associated with the fundamental band, and those associated with B_1 have been set to zero for the lines associated with the second band (lines 11–20). This enables you to perform a single linear regression on all 20 spectral lines and determine the **six** parameters and associated uncertainties at the same time (giving the most accurate results). Complete the linear regression noting the uncertainties in your derived parameters (you will need to use the magnitude of the uncertainties to report the parameters to the appropriate level of significance).

Finally you need to use the intensity data of the fundamental band to determine the temperature of your data. Note that the intensity has been normalized to the $R(0)$ transition. This means that the intensity of each spectral line is equal to $g.\exp(-\Delta E/kT)$, where g is the degeneracy of the initial quantum state of the transition and ΔE is the difference in energy between the initial quantum state and the $J = 0$ state. When determining the temperature using the intensity data, the most accurate method will be to do a least squares analysis and to minimise using Solver. I will provide a weblink shortly to show how Solver can be used to do least squares analysis. Other less accurate methods for determining temperature will be awarded fewer marks. (The approximate division of marks is 80% for the linear regression and 20% for the determination of temperature.)

Report your results to the online survey, **homework assignment 3**. You have until **11.59pm Tuesday 15 March** to complete this assignment.

Your spectral data are as follows:

spectral line	frequency, v / cm^{-1}	intensity
1	277.43532781795807	4.3170731663162814
2	277.60559762473804	4.7602005338632596
3	277.77519731634209	4.8173602723559865
4	277.94413484969601	4.1246680506406523
5	278.11239933049001	2.8327792987180249
6	278.44693331644203	1
7	278.61319178525605	2.8144329793379912
8	278.77878829225006	4.1605108654683898
9	278.94370367794409	4.7731550292054505
10	279.10795380179405	4.8235634681731874
11	554.0753276487261	—
12	554.245596745336	—
13	554.41519706551605	—
14	554.58413129884605	—
15	554.75239791619413	—
16	555.08693430161406	—
17	555.25319448692403	—
18	555.41878650322599	—
19	555.58370707467213	—
20	555.74795859770802	—

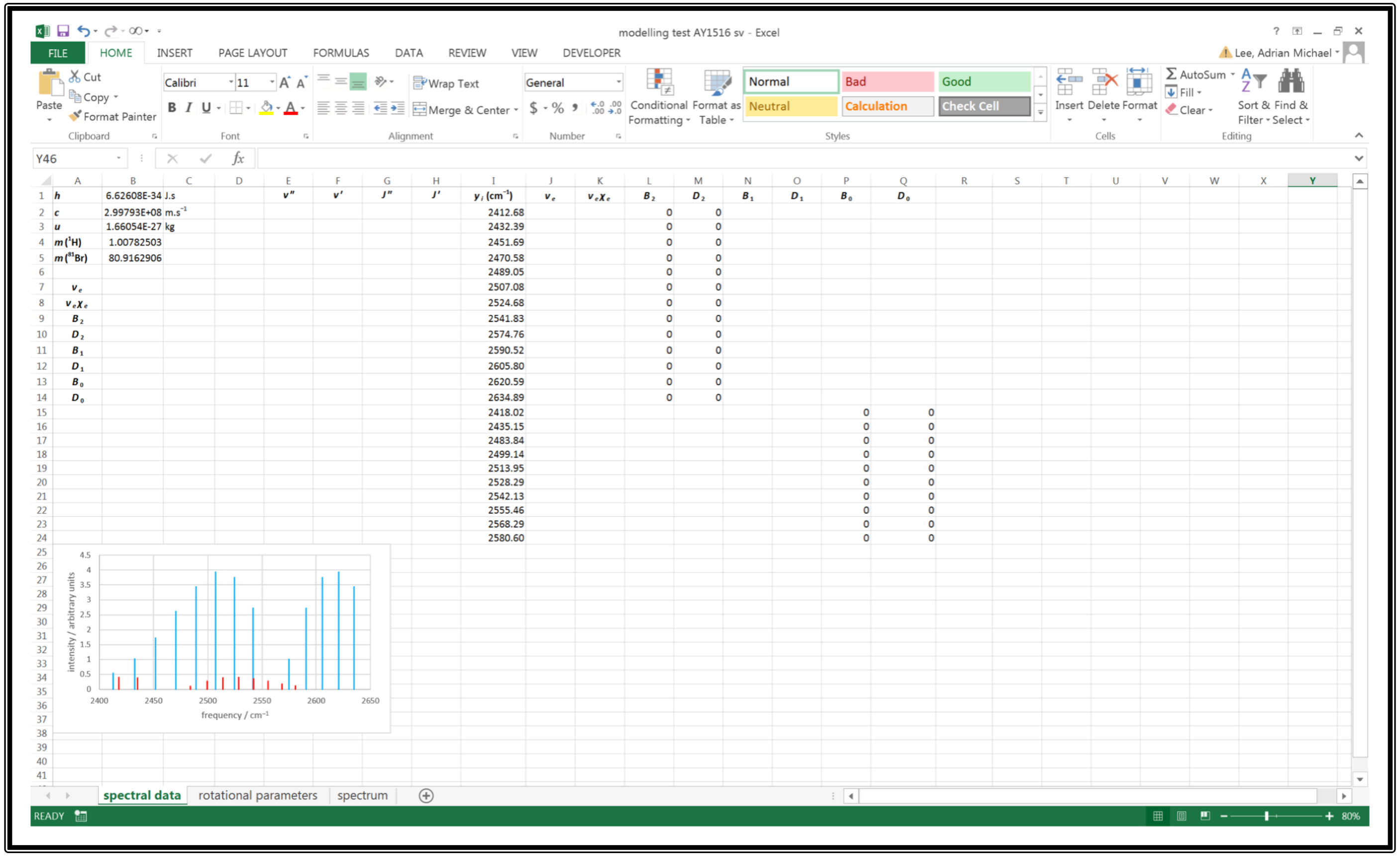
The equations in the Excel spreadsheet do not come out well in old versions of Excel. They should have the following form:

$$\tilde{S}(v,J) = (v+\tfrac{1}{2})\tilde{\nu}_e - (v+\tfrac{1}{2})^2\tilde{\nu}_e\chi_e + \tilde{B}_v J(J+1) - \tilde{D}_e J^2(J+1)^2$$

$$y_i = \tilde{S}(v',J') - \tilde{S}(v'',J'') = \tilde{\nu}_e.x_1 + \tilde{\nu}_e\chi_e.x_2 + \tilde{B}_2.x_3 + \tilde{B}_1.x_4 + \tilde{B}_0.x_5 + \tilde{D}_e.x_6$$

Align Assessment

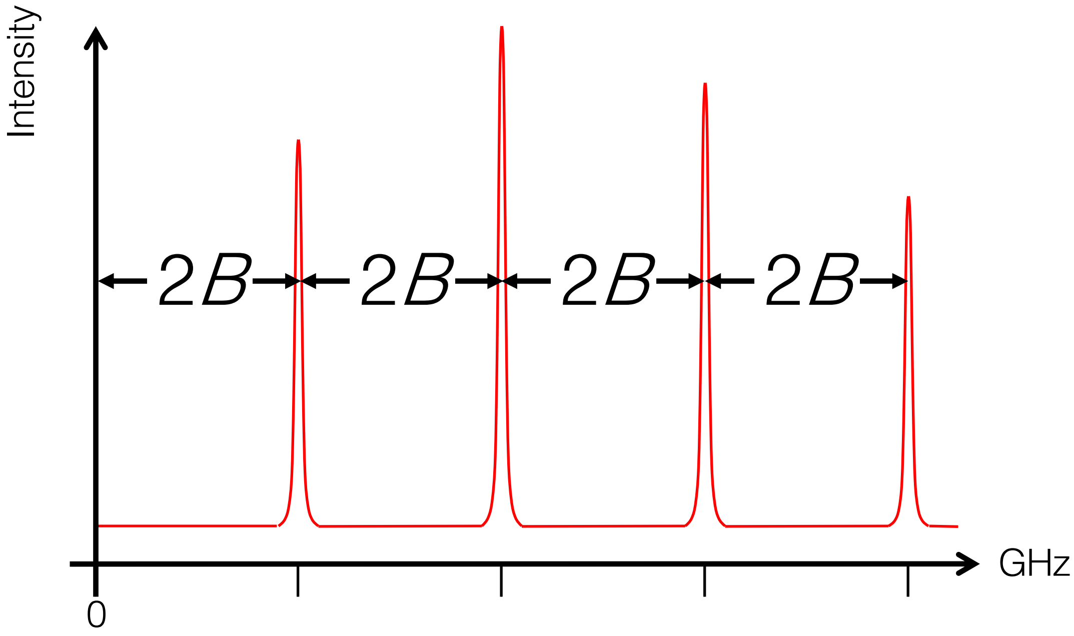
- Open-book modelling test



Creating a Prototype

Features of a Rotational Spectrum

Rotational Spectrum



Does it Work?

Improved Learning in a Large-Enrollment Physics Class

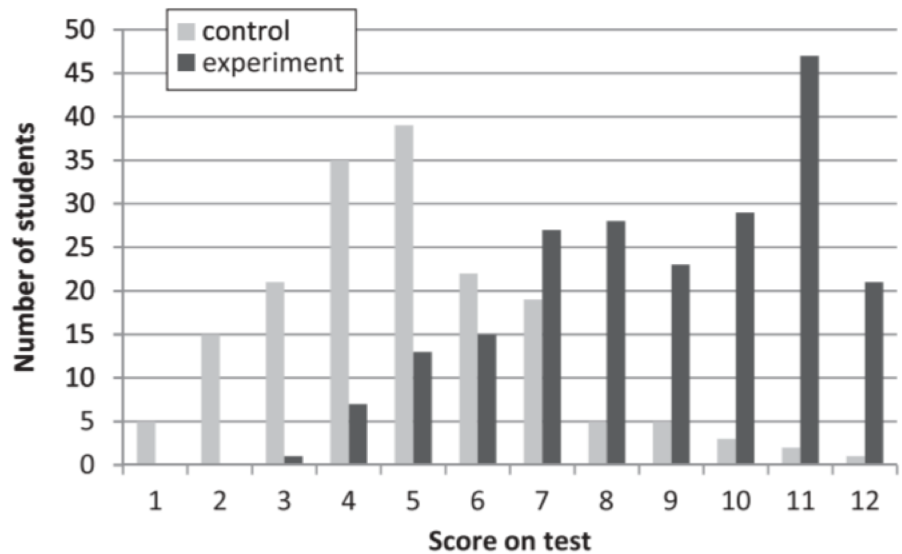
Louis Deslauriers,[1,2] Ellen Schelew,[2] Carl Wieman*†‡

We compared the amounts of learning achieved using two different instructional approaches under controlled conditions. We measured the learning of a specific set of topics and objectives when taught by 3 hours of traditional lecture given by an experienced highly rated instructor and 3 hours of instruction given by a trained but inexperienced instructor using instruction based on research in cognitive psychology and physics education. The comparison was made between two large sections ($N = 267$ and $N = 271$) of an introductory undergraduate physics course. We found increased student attendance, higher engagement, and more than twice the learning in the section taught using research-based instruction.

from any particular practice but rather from the integration into the overall deliberate practice framework.

This study was carried out in the second term of the first-year physics sequence taken by all undergraduate engineering students at the University of British Columbia. This calculus-based course covers various standard topics in electricity and magnetism. The course enrollment was 850 students, who were divided among three sections. Each section had 3 hours of lecture per week. The lectures were held in a large theater-style lecture hall with fixed chairs behind benches grouping up to five students. The students also had weekly homework assignments, instructional labo-

Fig. 1. Histogram of student scores for the two sections.



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*On leave from the University of British Columbia and the University of Colorado.

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‡This work does not necessarily represent the views of the Office of Science and Technology Policy or the United States government.

(agreement with physicist)		
Mean midterm 1 score	59 ± 1%	59 ± 1%
Mean midterm 2 score	51 ± 1%	53 ± 1%
Attendance before experiment*	55 ± 3%	57 ± 2%
Attendance during experiment	53 ± 3%	75 ± 5%
Engagement before experiment*	45 ± 5%	45 ± 5%
Engagement during experiment	45 ± 5%	85 ± 5%

*Average value of multiple measurements carried out in a 2-week interval before the experiment. Engagement also varies over location in the classroom; numbers given are spatial and temporal averages.

DesLauriers, L., E. Schelew and C. Wieman (2011) Improved learning in a large-enrollment physics class, *Science*, **332** 862–864.

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a],

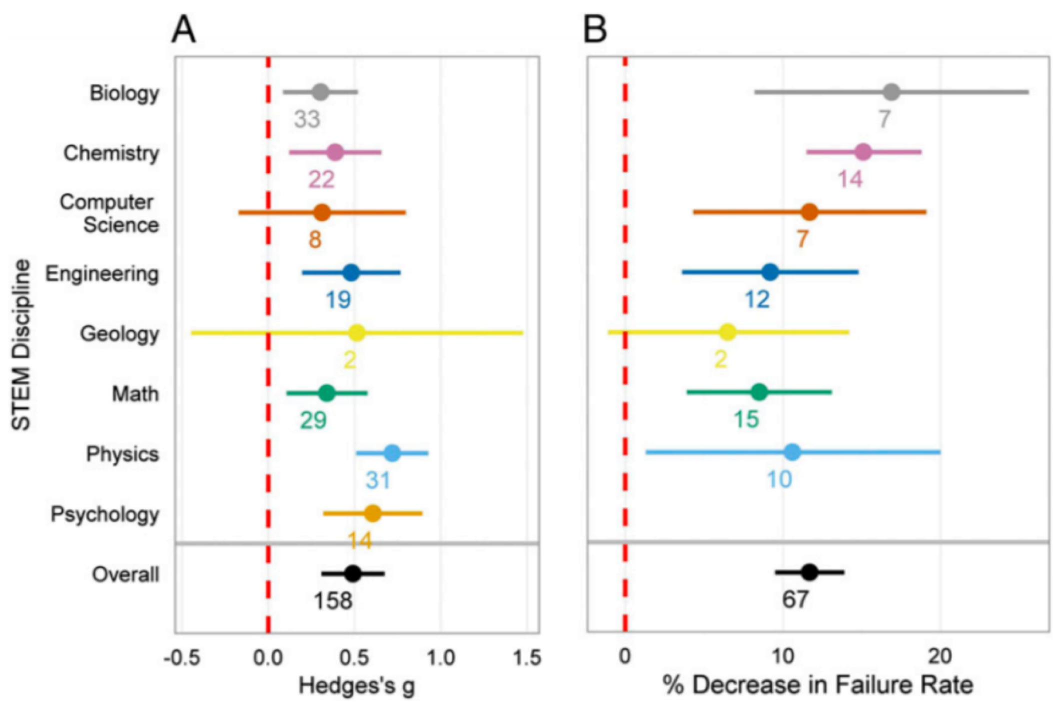

Fig. 2. Effect sizes by discipline. (*A*) Data on examination scores, concept inventories, or other assessments. (*B*) Data on failure rates. Numbers below data points indicate the number of independent studies; horizontal lines are 95% confidence intervals.

constructivism | undergraduate education | evidence-based teaching | scientific teaching

tional lecturing—a difference that represents a 55% increase (Fig. 1 and Fig. S1).

Freeman, S., S. L. Eddy, M. McDonough, M. K. Smith, N. Okoroafor, H. Jordt and M. P. Wenderoth. (2014) Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*. **111**, 8410–8415.

Peer Instruction: Ten years of experience and results

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(Received 21 April 2000; accepted 15 March 2001)

We report data from ten years o
algebra-based introductory physics
mastery of both conceptual reasonin
also discuss ways we have improve
notably, we have replaced in-class r
introduced a research-based mecha
cooperative learning into the discus
intended to help students learn more
the discussion sections, and are acco
American Association of Physics Teachers.
[DOI: 10.1119/1.1374249]

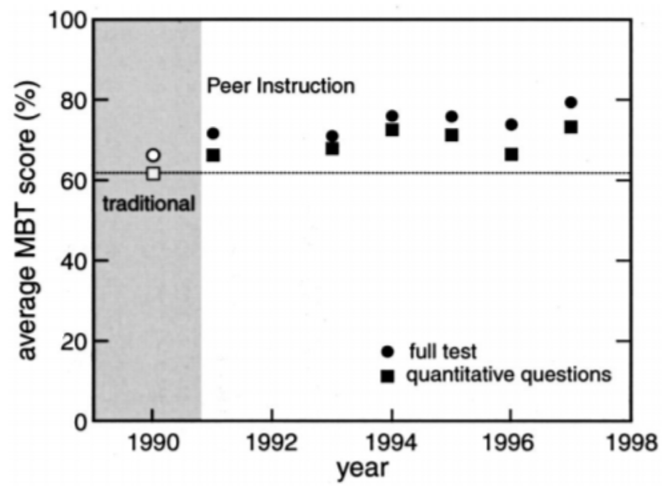
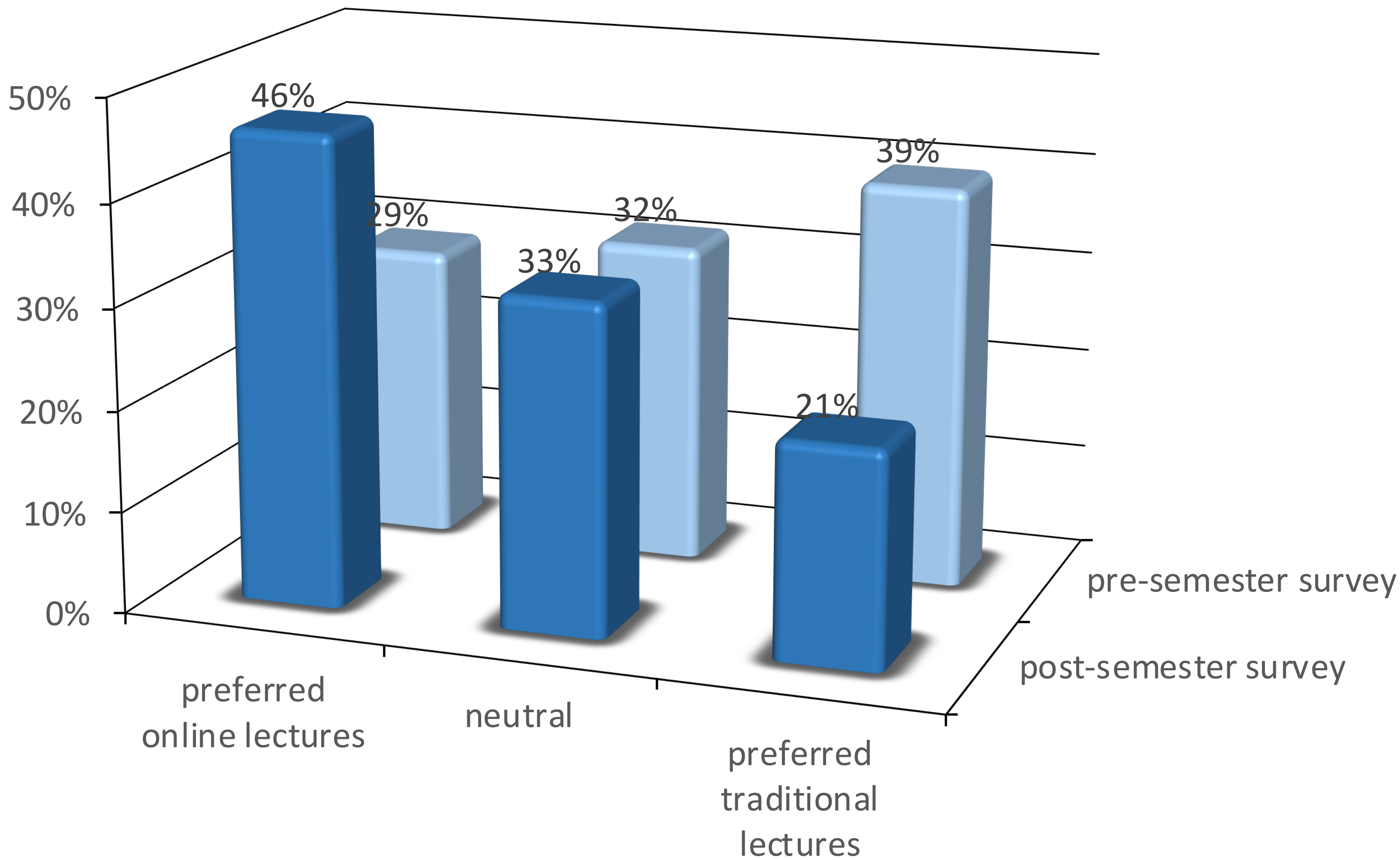


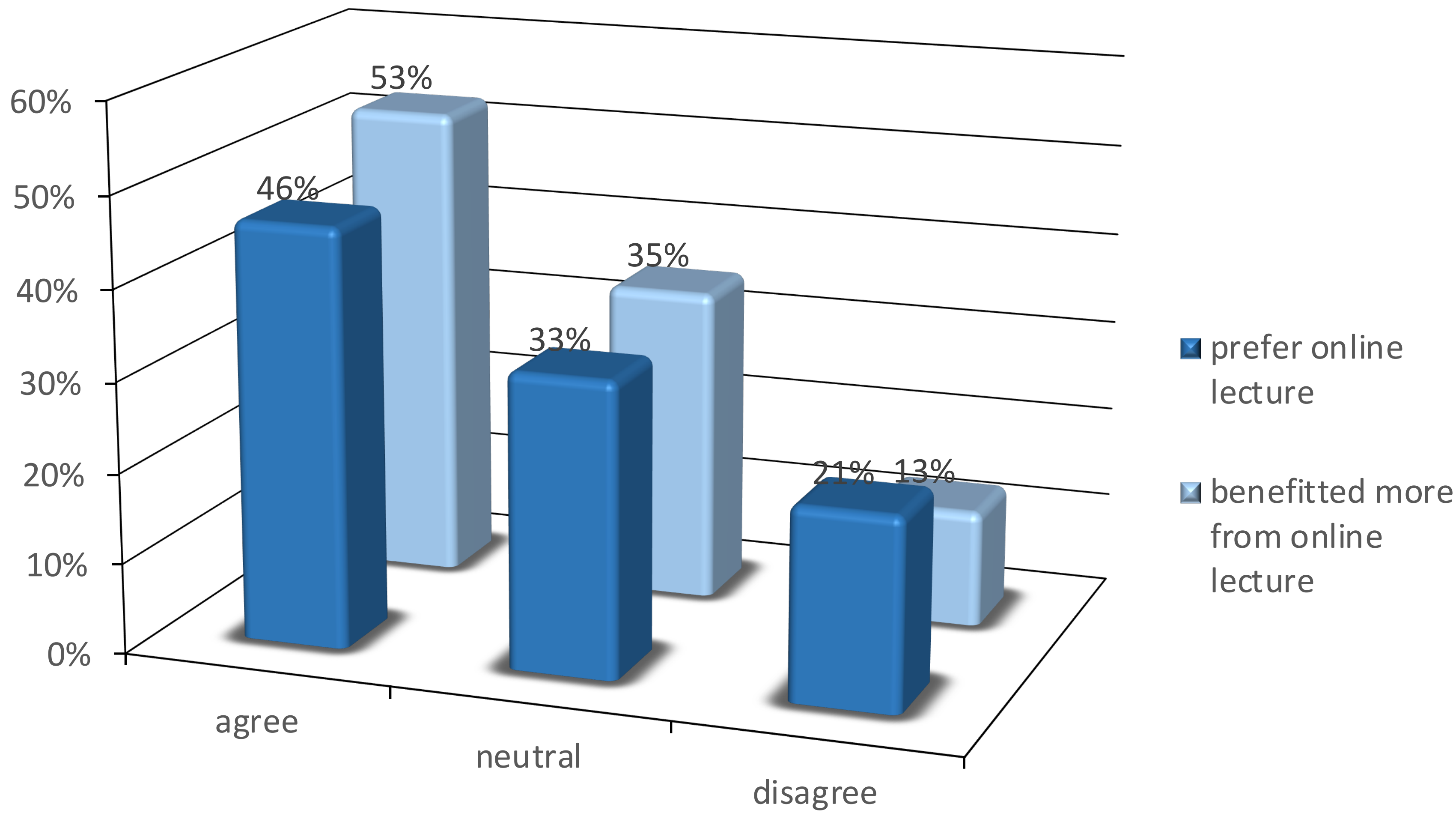
Fig. 3. Mechanics Baseline Test (Ref. 13) scores for introductory calculus-based physics, Harvard University, Fall 1990–Fall 1997. Average score on entire test (circles) and on quantitative questions (Ref. 17) only (squares) vs year are shown. Open symbols indicate traditionally taught courses and filled symbols indicate courses taught with PI. The dotted line indicates performance on quantitative questions with traditional pedagogy (1990).

Crouch, C., and E. Mazur. (2001) Peer Instruction: Ten Years of Experience and Results, *American Journal of Physics*, 69, 970–977.

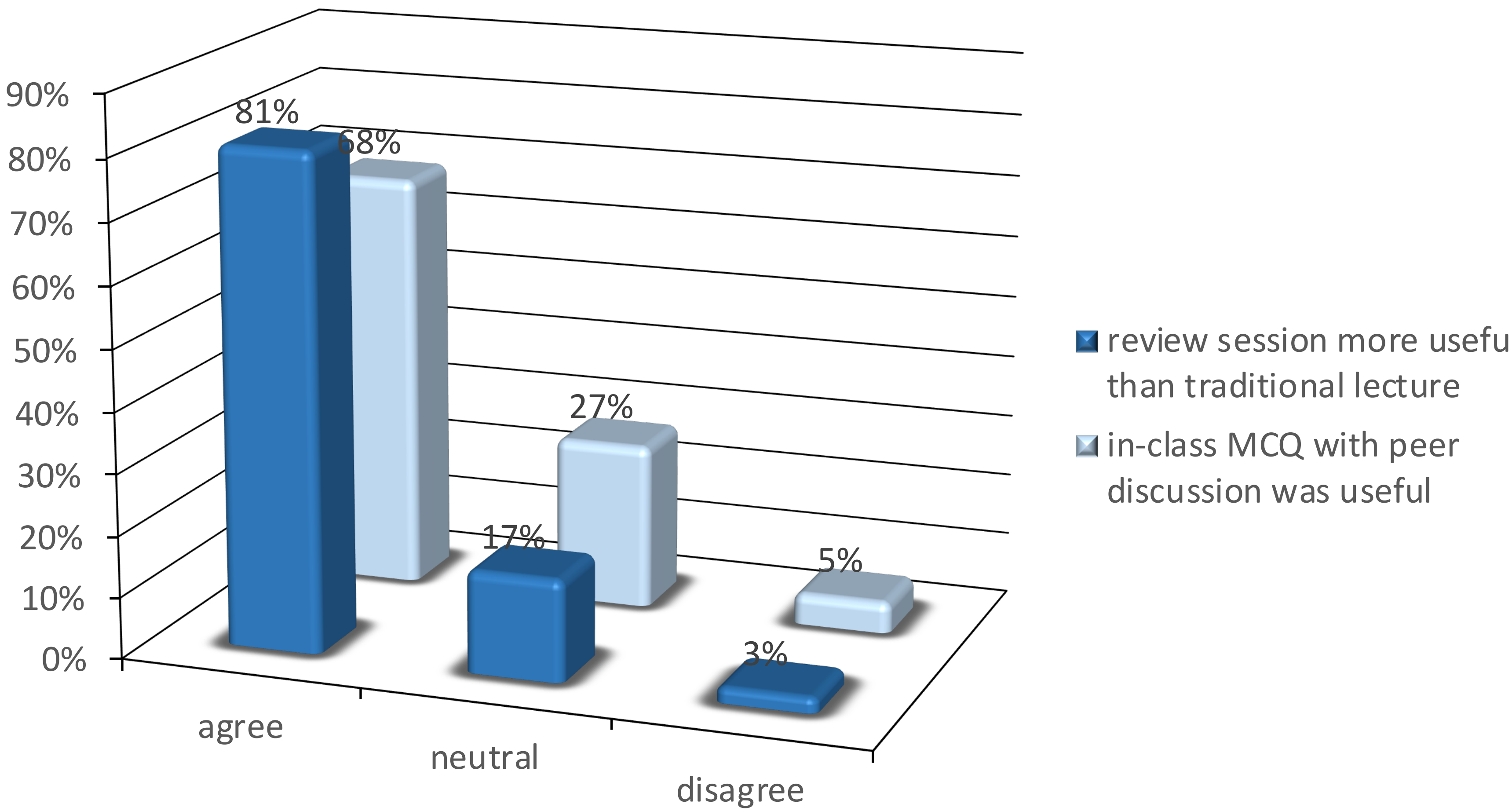
Student Feedback: Online lectures



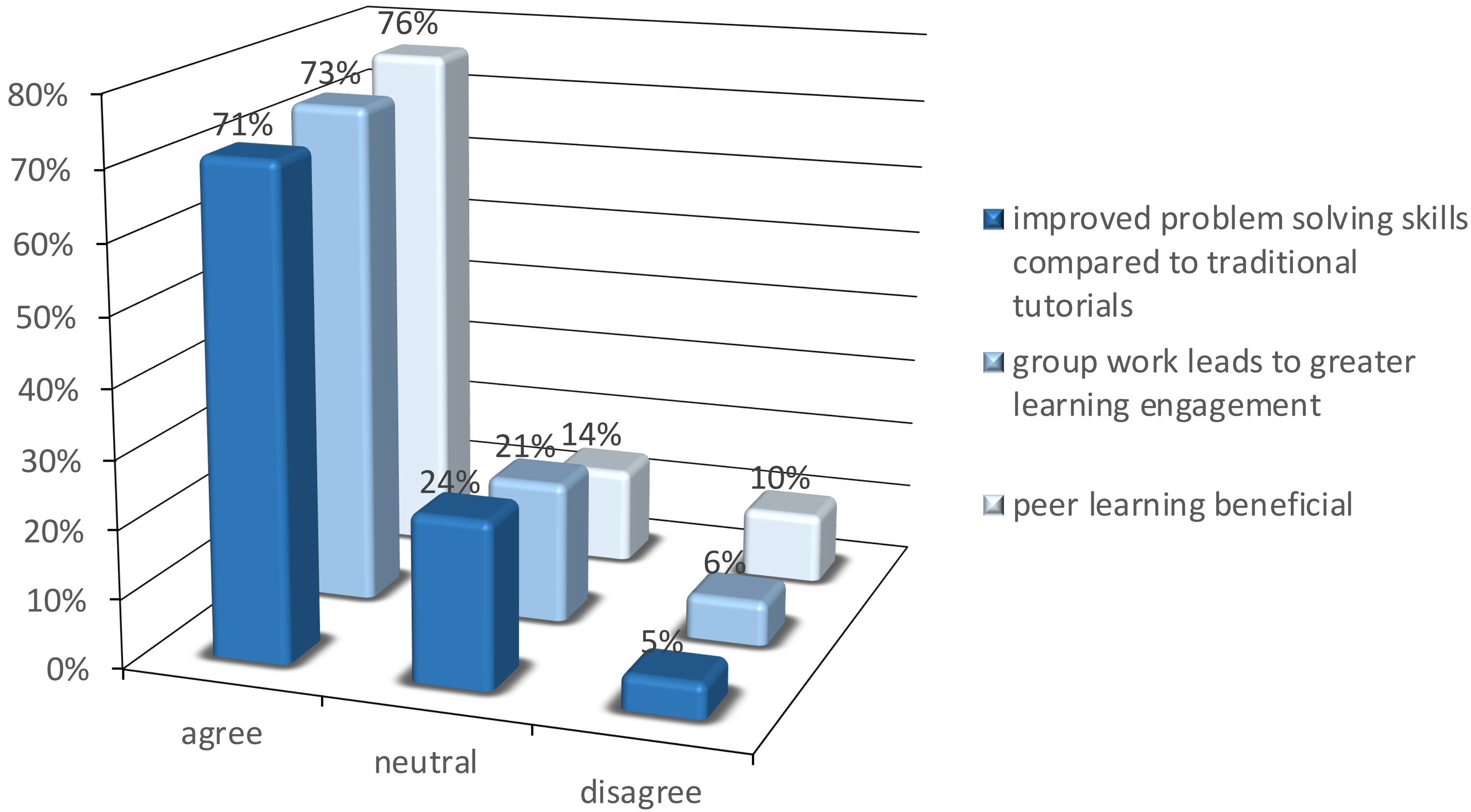
Student Feedback: Online lectures



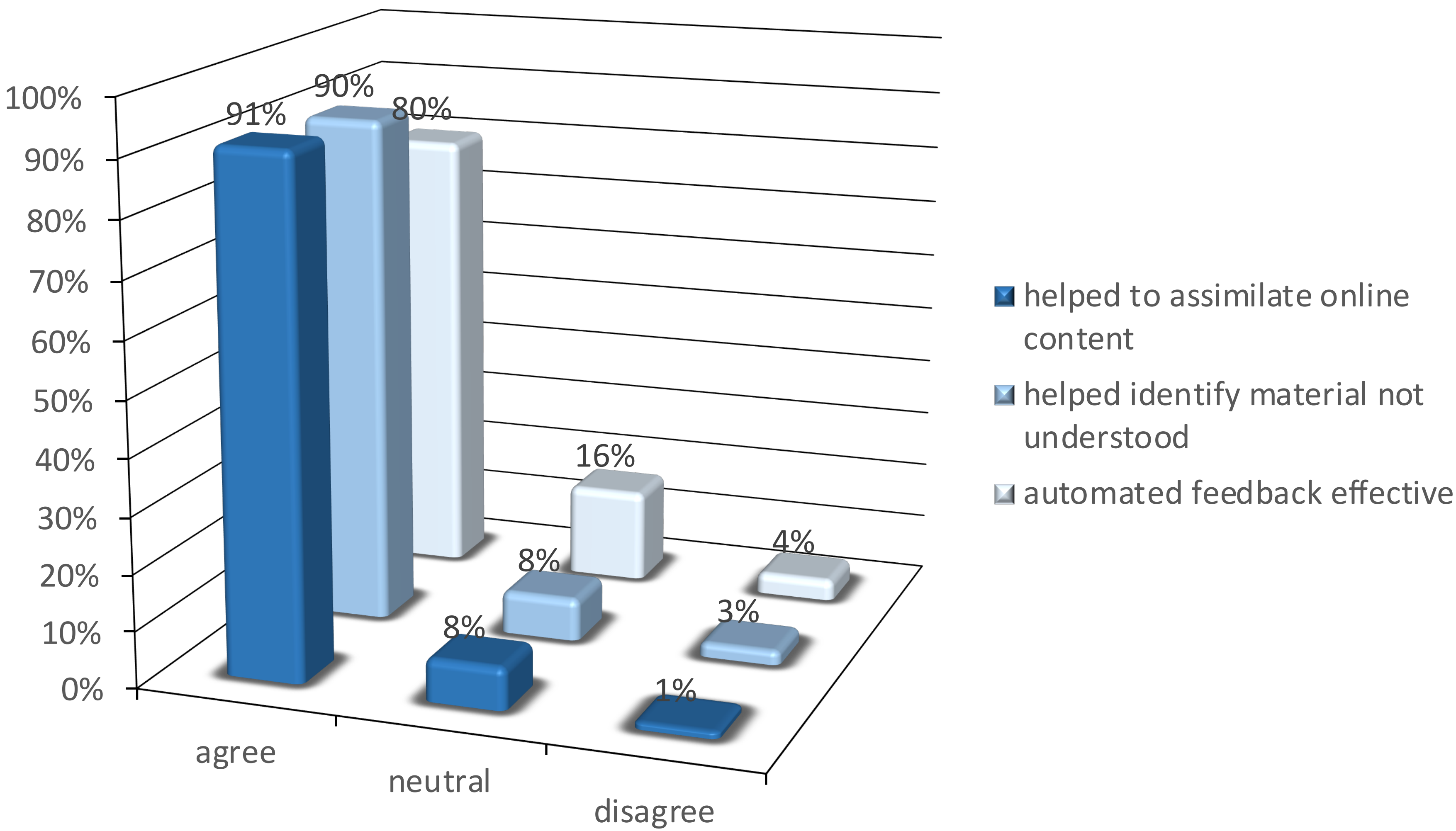
Student Feedback: Large class review sessions



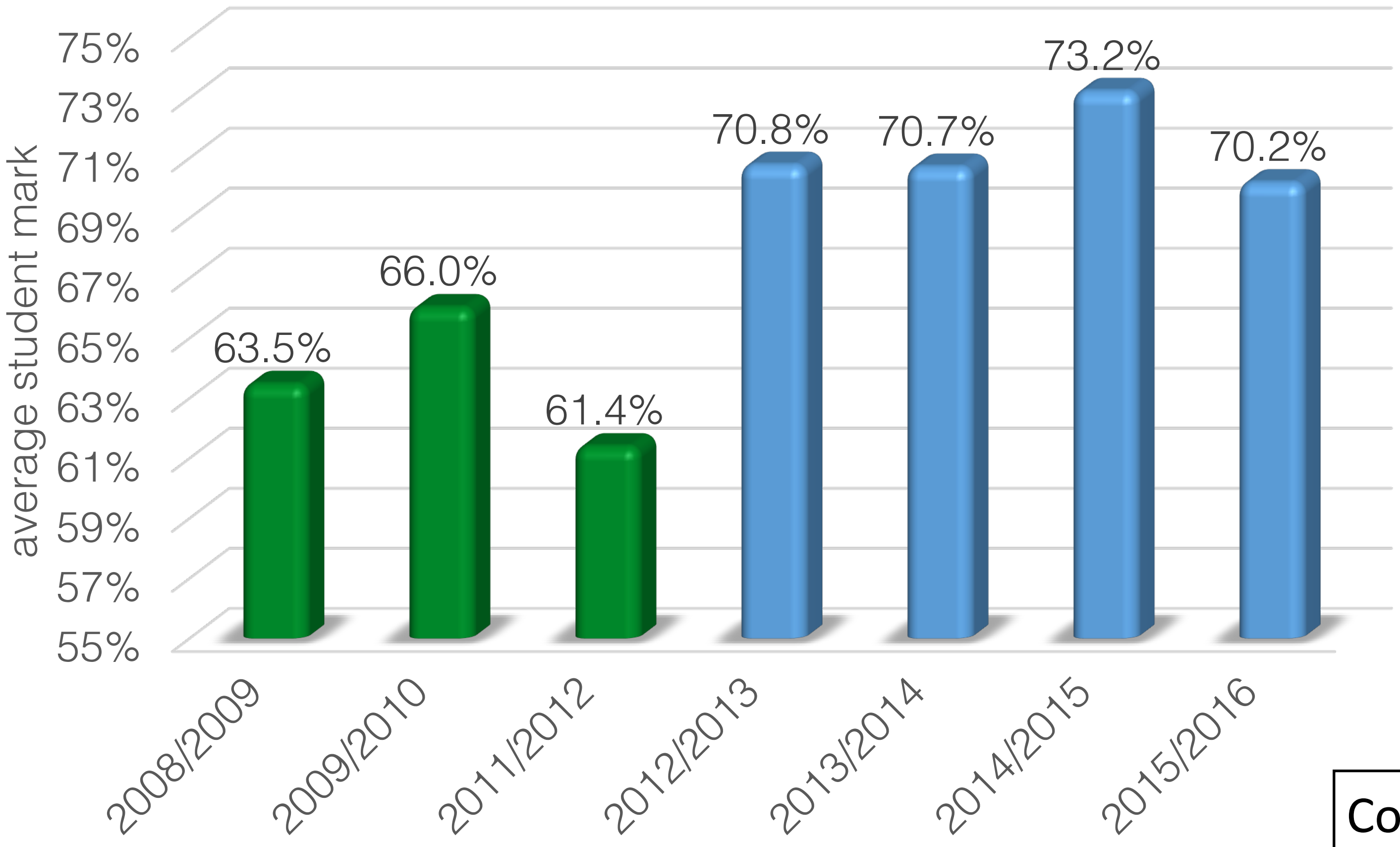
Student Feedback: Active learning tutorials



Student Feedback: Weekly online quizzes

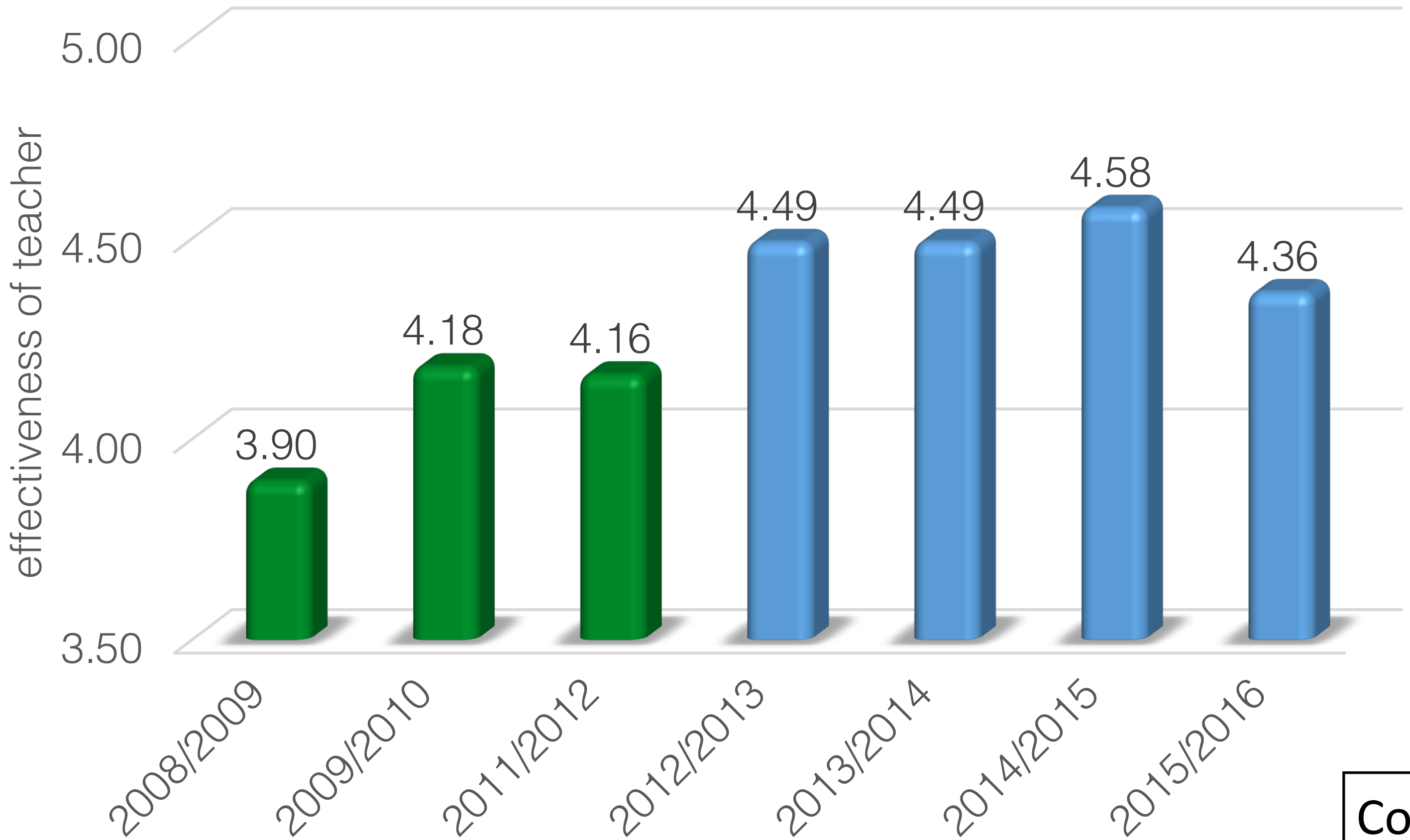


Student Learning Gain



Cohen's d = 0.59
p value < 10^{-16}

Effectiveness of Teacher



Cohen's d = 0.57
p value $< 10^{-22}$

Thinking about flipping?

1. What learning environments do you have available?
2. How would you use your timetabled face-to-face contact time?
3. How will you ensure that your students are prepared for face-to-face class?
4. How would your face-to-face class differ from current practice?