Transformation of an Introductory Cell and Molecular Biology course from a large lecture-based format into an interactive student-centered environment

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Abstract and Introduction

We are currently involved in the transformation of our undergraduate Introduction to Cell and Molecular Biology course from a large lecture-based course to a more interactive student-centered format. Prior to beginning transformation, this course consisted of three lectures per week with 4 hourly exams and a final exam upon which the entire grade was based. We have since developed a set of course learning goals, added the use of clickers to the lectures, developed and administered a pre/post assessment for the course, provided students with practice exam questions, and developed weekly problem sets to facilitate practice with the material. In addition, the students have access to online tutorials tailored to the topics covered in lecture. During the transformation process, we have undertaken a study to compare the learning gains of students in the lecture course to those of students who also take part in small-group interactive sessions. We are also in the process of developing an Introductory Biology pre/post assessment tool linked to the newly developed learning goals for assessing student learning gains in response to the transformed course format.

To assess the effects of interactive collaborative learning on student performance, we offered students in the large lecture-based introductory biology course the opportunity to supplement lectures with small-group, interactive weekly learning sessions (manuscript in preparation). Student volunteers were divided into two experimental cohorts, as well as a control cohort of students who volunteered but could not participate because of scheduling conflicts. The first experimental cohort, led by a teaching assistant, participated in interactive review sessions on misconceptions and difficult concepts. The second cohort participated in peer-driven active learning sessions on these topics, facilitated by a pair of undergraduate learning assistants. These two cohorts were compared with each other and the control cohort. Students in the two experimental cohorts had significantly higher learning gains than the control cohort, while differences between the two experimental cohorts were minimal. Possible explanations for these observations are discussed.

A validated assessment tool designed to test conceptual understanding of the main course learning goals (manuscript in preparation) was given the first week of class to measure student's incoming knowledge of molecular and cell biology concepts. The same assessment was re-administrated as part of the final exam (post-assessment). This assessment tool provided a measure of student learning gains during the semester.

Introduction to Cell and Molecular Biology Transformation: Fall 2005 vs Fall 2008

Fall 2005	Fall 2008
50 minute lectures (MWF)	50 minute lectures (MWF)
3 hourly exams	Course level and topic learning goals
final exam	Pre-post assessment
	Concept based problem sets (online)
	Interactive clicker questions in lecture
	3 hourly exams
	final exam
	Surveys (data collection for SEI project)
Text: Essential Cell Biology, Alberts	Text: Biological Science, Custom Ed., Scott Freeman
	Online tutorials (MasteringBiology)
Exams = 100% of grade	*Exams = 100% of grade*
	Optional interactive co-seminar (for credit; run by LAs and TAs)

Interactive Group Study

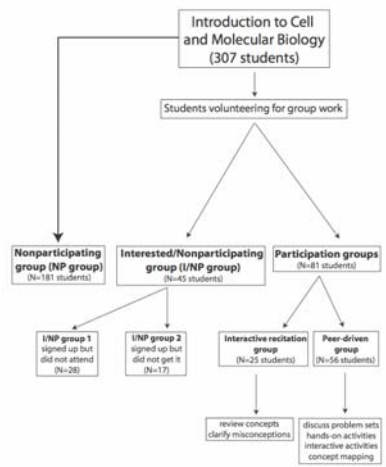

Figure 1. Design of student groups. A total of 374 students were enrolled in the Fall 07 Introductory Cell and Molecular Biology course. The 307 students who completed the course and took both the pre- and post-assessment were included in this study. In total, 67 students were excluded from this study because they did not complete the course (40 students), they only attended the working group for one session (10 students), they had no learning gains or negative learning gains (11 students) (see materials and methods), or 4) they took the pre-assessment but not the post-assessment (6 students).

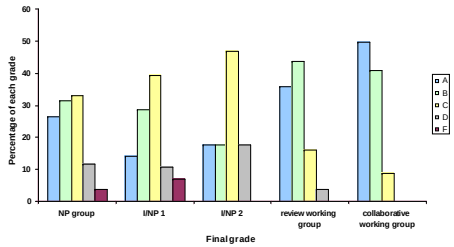

Figure 2. Course grade distribution for each student cohort. The majority of students in the collaborative working group achieved an "A" grade in the course. The majority of students in the review working group achieved a "B" grade, while the majority of students in the remaining groups achieved "C" grades.

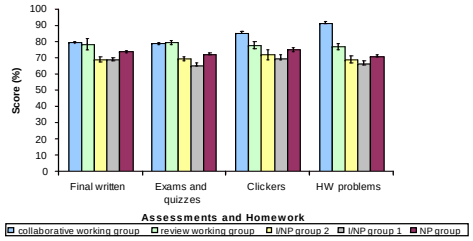

Figure 3. Student performance on graded assessments. Students in both working groups outperformed students in the NP group on the final written exam ($p<0.01$, two-tailed t test), two hourly exams and quizzes ($p<0.01$, two-tailed t test). Students in the collaborative working group out-performed the NP group on the graded clicker questions ($p<0.05$, two-tailed t test), and out-performed all groups on the problem sets ($p<0.001$, ANOVA).

Table 1. Average pre-assessment scores[1]

Group	Pre-assessment average scores +/- SE (N)[2]
Entire Class	42.0 +/- 0.76 (307)
Collaborative working groups[3]	42.0 +/- 1.80 (56)
Review working groups3	37.7 +/- 3.09 (25)
NP group	42.2 +/- 1.0 (181)
I/NP group 1	45.3 +/- 2.78 (28)
I/NP group 2	40.6 +/- 2.71 (17)

[1] Data include only GPAs (?) of students who took both the pre- and post- assessment and completed the course.
[2] Mean +/- Standard Error, with the number of students (N) in each group. There was no significant difference in the means between the groups (one-way ANOVA Post Hoc Tukey analysis).
[3] Data for the 4 collaborative working groups and 2 review working groups were averaged.

Table 2. Working group attendance

Group	Attendance (number of times)		
	(2-4)	(5-7)	(8-11)
Collaborative working groups	1.8% (1)	7.1% (4)	91% (51)
Review working groups	24% (6)	28% (7)	48% (12)

Table 3. Average final grade in different student groups

Group	Average final score (%) (Mean[1] +/- Std. Error)
NP group	73.4 +/- 0.1 (194)
I/NP group 1	69.9 +/- 0.2 (31)
I/NP group 2	70.7 +/- 0.3 (17)
Review working groups	80.2* +/- 0.2 (25)
Collaborative working groups	83.2* +/- 0.9 (56)

[1] values are mean +/- Std. Error, with n in parenthesis.
*p <0.05 when compare to the control group (I/NP group 2) (two-tailed t test).

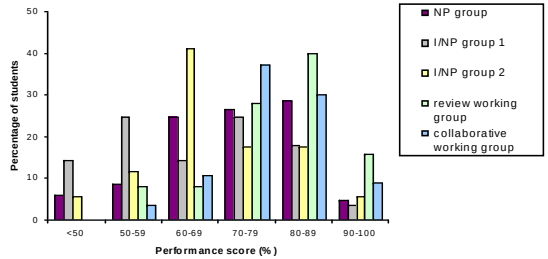

Figure 4. Graded performance scores for each group. The performance scores include all graded activities (exams, quizzes, clickers, and paper) except homework problem sets. The average performance scores for both small working groups were identical (80%+/-2.0) and significantly higher ($p<0.01$, two tailed t-test) than the NP group (70%+/-3.0), the I/NP 1 group (68%+/-3.0) and the I/NP 2 group (73%+/-9.7). The distribution of the performance scores peaked at a higher value for the collaborative working group (80-89) and the review working (70-79) than for the I/NP 2 group (60-69). Higher percentage of students in both working groups achieved a higher range of performance scores (i.e. >70) than other student groups. No students from both types of working groups had the performance scores <50.

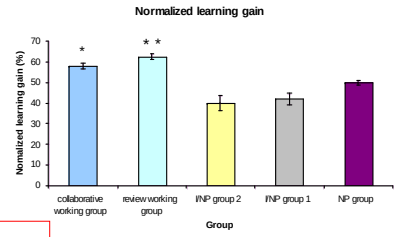

Figure 5. Student learning gains. Gains in conceptual understanding achieved by the end of the semester were measured by re-administering the pre-assessment as part of the final exam (the post-assessment). The conceptual learning gains were calculated only for those students who took both the pre- and post-assessment, and are were expressed as % of maximal possible learning gain. The average normalized learning gain for the entire class was 51% +/- 1.31. Students who participated in either working group had significantly higher learning gains (58% and 63% for collaborative and review working groups, respectively) than the NP group (41%) ($p<0.05$ and $p<0.01$ respectively). Students in either working group also had higher normalized leaning gains than I/NP groups 1 and 2.

Data for the 4 collaborative working groups and the 2 review working groups were averaged.
*p <0.05 **p<0.01 One-way ANOVA (Post Hoc Tukey) analysis.

Introductory Biology Concept Inventory

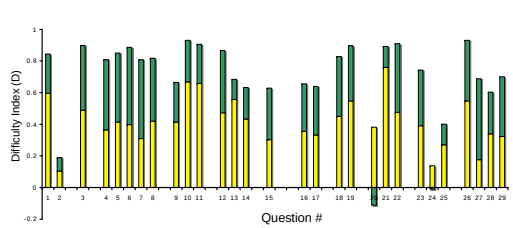

Figure 6. P values for each question on the biology concept assessment (pretest and posttest). P values represent the ratios of correct answers to the total number of responses. Results are based on 307 students who completed Introductory to Cell and Molecular Biology course in fall 2008 at University of Colorado. Lower values indicate more difficult questions. All except questions 20 and 24 shows an increase in correct answers as illustrated by different colored bars. Questions are grouped according to learning goals indicating the extent of student learning on the corresponding concepts.

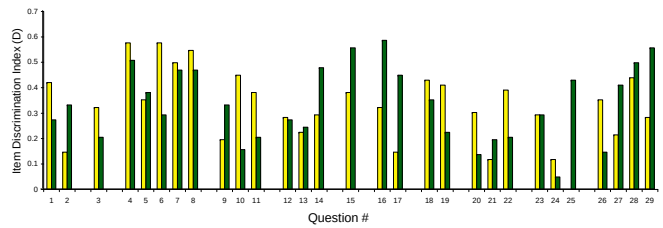

Figure 7. D values for questions on the biology concept assessment (pretest and posttest). Results were calculated (see below) from the same data set as in Figure 1. Questions that have higher D values more effectively discriminate students whose overall test scores identify them as strong or weak students (Doran, 1980). Questions that show high D values on the pretest (blue; only strong students answered them correctly) and low D values on the post test (purple; most students answered correctly) correspond to concepts on which most students gained understanding during the course. Questions with high D values on both pretest and posttest correspond to concepts that primarily only the stronger students understood at the end of the course. Questions are grouped according to learning goals.

Conclusions

Students in the experimental cohorts (review working group and collaborative working group) outperformed the control cohort in terms of overall course grade.

Students in both experimental cohorts significantly outperformed the control groups on the written portion of the final exam.

Students in the collaborative working group outperformed the NP group on graded clicker questions and outperformed all groups on the problem sets.

Students in either experimental cohort had significantly higher conceptual learning gains than the control cohorts.

Data from this study performed on the class from Fall 2007 were used to support the decision to offer an optional "collaborative" co-seminar (for credit) for students in the Fall 2008 course.

The Introductory Biology Concept Assessment used in this study is currently undergoing refinement and validation by interviews of previous students and introductory biology experts.

Table 4. Mean pretest, posttest, and learning gain scores for students, TAs/LAs, and introductory biology experts

	n[a]	Mean pretest (+/-SE), %	Mean posttest (+/-SE), %	Mean learning gain (+/-SE), %
Students	307	41.6 (+/- 0.8)	71.4 (+/- 0.9)	54.0 (+/- 0.8)
TAs/LAs	14	75.5 (+/- 0.3)	84.5 (+/- 1.1)	44.7 (+/- 7.8)
Biology experts	10	NA[b]	90.0 (+/- 5.4)	NA[b]

[a] Number of people who took the IBCA[c]. Students were enrolled in introductory biology at CU. TAs and LAs were graduate and undergraduate students, respectively, at CU. Biology experts from several institutions (see text) who took the IBCA are included for comparison.
[b] NA, not applicable.
[c] IBCA: Introductory Biology Concept Assessment