The Colorado Learning Attitudes about Science Survey (CLASS) for use in Biology

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Introduction

Over the last decade there has been a strong call to improve biology undergraduate education (e.g. HHMI, 2002; NRC, 2003; Handelsman *et al.*, 2004; Wood, 2009; Woodin *et al.*, 2009). The main goals of this charge are to advance students' conceptual content knowledge to a deeper more expert-like level and to help students develop both expert-like approaches to problem solving and more sophisticated perceptions about how biology knowledge is structured. An important step in achieving these goals is to create assessments that measure whether curricular and pedagogical changes in the classroom are succeeding in both improving student learning and transitioning students towards more expert-like thinking (reviewed in Garvin-Doxas *et al.*, 2007; Woodin *et al.*, 2009, Knight, 2010). The CLASS-Bio helps accomplish the latter goal by directly comparing student perceptions about the discipline of biology to expert perceptions.

Here we briefly provide information on the CLASS-Bio development, evidence of validity and comparison with the CLASS-Physics and CLASS-Chemistry. We then focus on results from the initial use of the CLASS-Bio across four universities.

CLASS-Bio Development & Validity

Table 1. Sequence of CLASS-Bio Development

1) Examined CLASS-Phys and -Chem for statements that could apply to the CLASS-Bio
2) Met with faculty working groups to determine which statements should be included
3) Interviewed students (n=39) and modified statements based on student responses
4) Solicited expert opinions and responses to statements (n=69, across 30 universities)
5) Gave pilot version (Fall07, n=627) and performed factor analysis to determine student thinking categories (following methods in Adams *et al.* 2006)
6) Revised statements and solicited additional feedback from faculty working groups, student interviews, and experts
7) Administered final version (Fall08, n=673) and performed a second independent factor analysis (following methods in Adams *et al.* 2006, using Pearson correlation matrix)
8) Verified category robustness using a polychoric correlation matrix (designed for ordinal data)

Table 2. CLASS-Bio Categories and Robustness Indicators (RI)[a]

CLASS Category	Statements	RI (Pearson)	RI (Polychoric)
Real World Connection	**2, 12, 14, 16**, 17, **19**, 25	6.74	8.26
Enjoyment (Personal Interest)	1, **2**, 9, **12**, 18, 27	10.0	10.0
Problem-Solving Reasoning	**8, 14, 16, 17, 24**	6.57	7.38
Problem-Solving Synthesis & Application	**3**, 5, **6**, **10**, **11**, **21**, 30	7.10	8.96
Problem-Solving Strategies	**7, 8, 20, 22**	7.14	7.09
Problem-Solving Effort	**8, 12, 20, 22, 24**, 27, 30	6.62	7.53
Conceptual Connections / Memorization	**6, 8, 11**, 15, **19**, 23, 31, 32	5.61	7.19
Uncategorized questions	**4, 13**, 26, **29**	n/a	n/a

[a]Statements in **bold** appear on the CLASS-Phys and CLASS-Chem (in either the same or slightly modified forms) although not necessarily in the same categories. Robustness indicators, calculated with either the Pearson or polychoric correlation matrices, range from 0-10, with 10 being most robust.

Table 3. Additional measures of CLASS-Bio validation

Reliability: Test-retest coefficient of stability (comparing all pre-responses of students in Fall07 and Fall08 to indicate that populations assumed to be similar over time are)	Percent favorable, r=0.97 Percent neutral, r=0,91 Percent unfavorable, r=0.97
Concurrent Validity: Testing whether the assessment can detect differences between populations when they are expected	Majors have significantly higher percent scores than non-majors (see Figure 1)

The Science Education Initiative at the University of Colorado provided funding for this project.

Figure 1. Majors demonstrate more expert-like perceptions of biology than non-majors

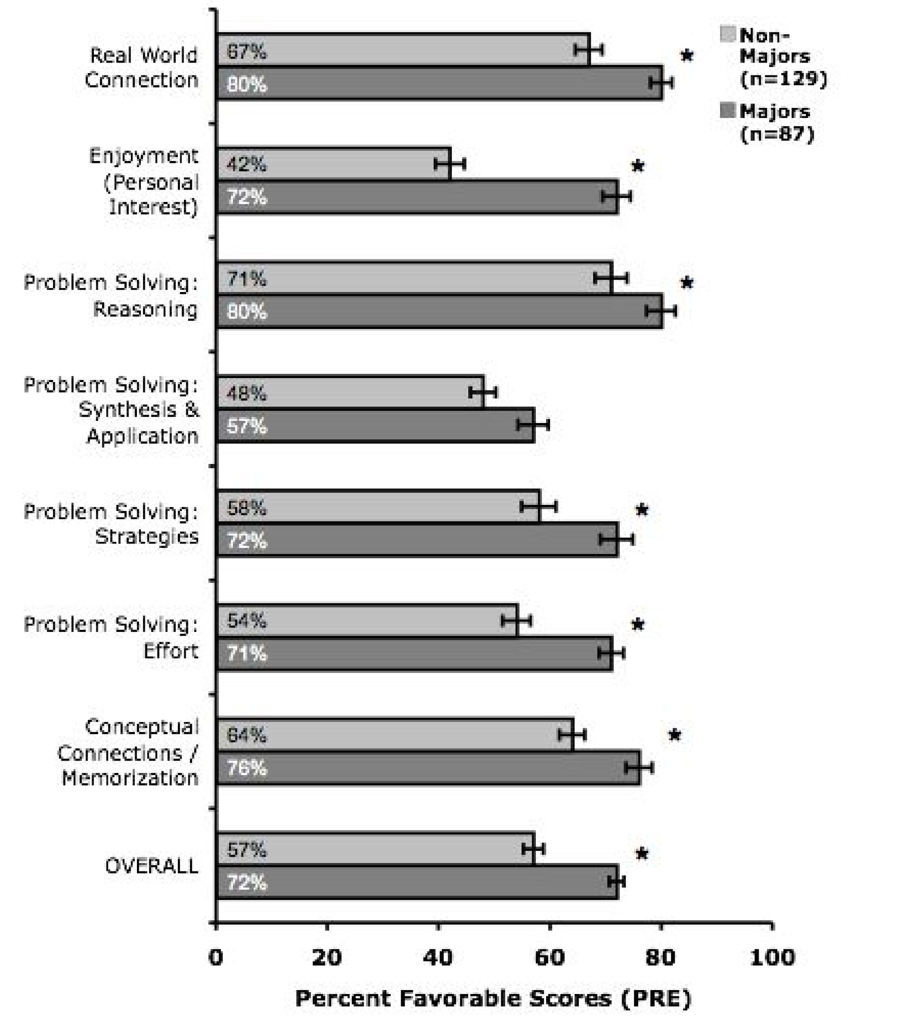

Figure 1. Differences in CLASS-Bio percent favorable scores between majors and non-majors entering an introductory biology course. Percent favorable scores are measures of percent agreement with the experts (see text for details). Asterisks indicate that majors have significantly higher scores entering an introductory course than non-majors in that category (>2 SEM).

Figure 2. Introductory Courses but not Upper Division Courses show more novice-like thinking post instruction

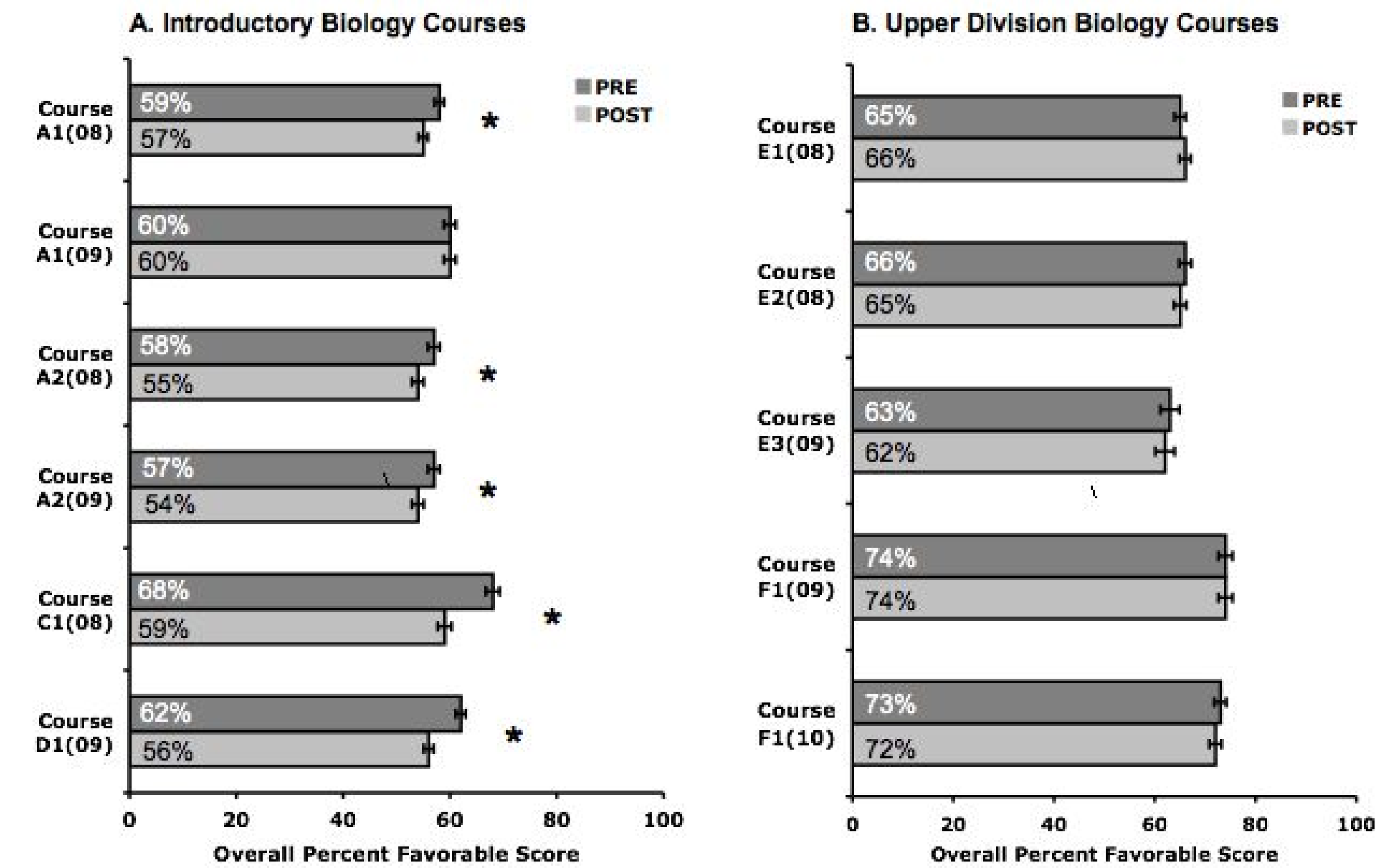

Figure 2. Overall pre- and post- instruction percent favorable scores (percent agreeing with expert) in introductory (A) and upper division (B) courses. Courses are coded by course (letter), instructor (number), and year. Introductory courses are represented by two CU departments (EBIO and MCDB) and one UBC department (Biology) while upper division courses are represented by two CU departments (MCDB and IPHY). Sample sizes are as follows: (A1'08, n=370; A1'09, n=336; A2'08, n=287; A2'09, n=265; C, n=170; D, n=504; E1, n=126; E2, n=130; E3, n=126; F'09, n=81; F'10, n=79). Asterisks indicate significant differences between pre- and post- instruction scores based on *paired student data* (> 2 SEM).

Figure 3. Within two different curricula series, biology students entering upper division courses have comparable or more expert-like thinking than students entering or exiting introductory courses

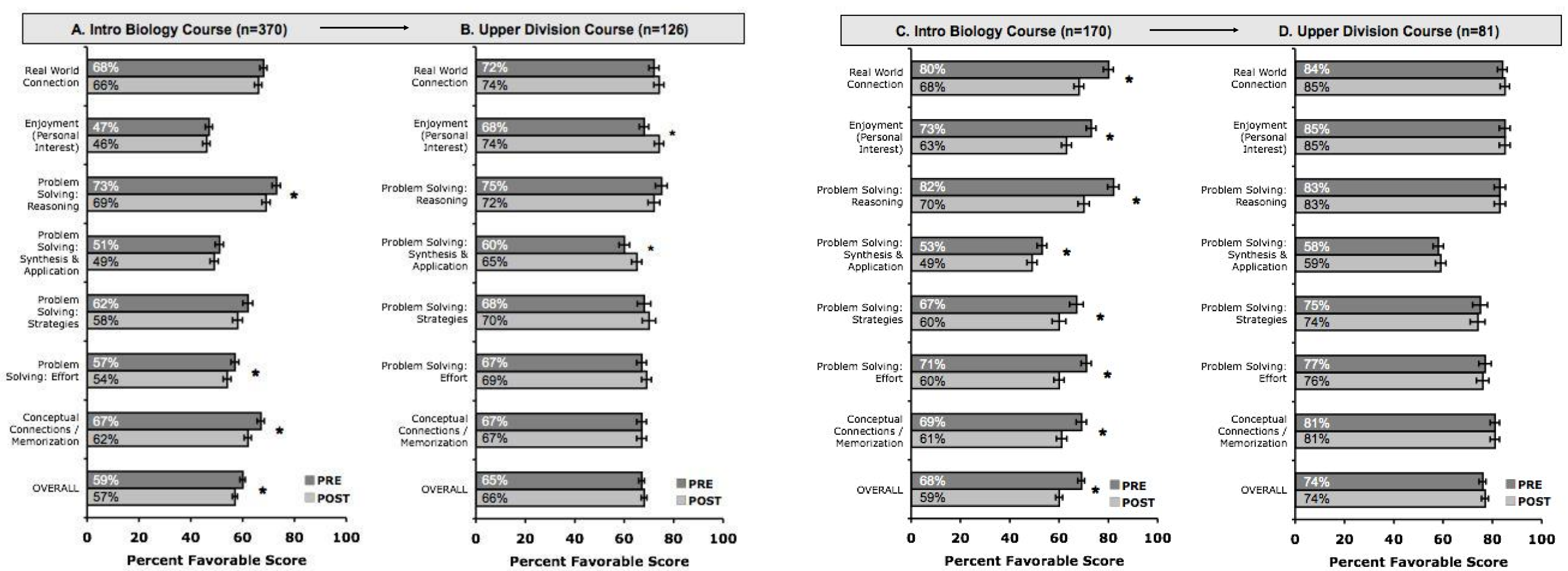

Figure 3. Pre- and post-instruction scores for CLASS-Bio categories in two example curricula with the introductory course of the series and an upper division course. For all categories in both curricula (A-B and C-D), pre-instruction scores in upper division courses are either comparable to or, in most cases, higher than either entering or exiting scores in each curriculum's introductory course. While data in both curricula series represent different pools of students between courses (i.e. data do not follow individuals through the curriculum), data across different semesters show consistent patterns of student thinking (see Figure 2). Asterisks denote significant shifts between pre- and post-instruction scores on paired student data within a given category (>2SEM).

Summary of Initial CLASS-Bio use

CLASS-Bio Development

- The CLASS-Bio has been rigorously tested for clarity and validity, is reliable across similar student populations, and can detect differences between majors and non-majors.

Perceptual Shifts Across Instruction

- Similar to CLASS results in Physics and Chemistry, overall CLASS-Bio scores become more novice-like following instruction in introductory biology courses but remain even across instruction in upper division courses (Fig. 2).
- In one of the introductory courses studied, (Course A1) novice-like shifts were eliminated following course changes (Fig. 2).

1. Students in some upper division courses have demonstrated more expert-like thinking following instruction in specific areas of student thinking (see Fig. 3B).

Recruitment and Retention

1. Students entering biology majors are most likely students that already enter college with expert-like perceptions rather than students who are gaining that expertise in their initial years. This is evidenced by the fact students entering upper division courses have higher CLASS-Bio scores than those exiting introductory courses (Fig. 3) and comparable scores to majors entering introductory courses (Fig. 1 and 3).

CLASS-Bio vs. CLASS-Phys, -Chem

1. While the CLASS-Phys and -Chem are very similar instruments, the CLASS-Bio varies considerably. Only 21 of the original 42 CLASS-Phys statements were viable on the CLASS-Bio and while many categories of student thinking are similar in nature, the statements that comprise them are different (no more than 50% of statements in any one category are the same).
2. Variation among instruments may reveal differences in the way students perceive biology. For example, on the CLASS-Bio "enjoyment" statements more often appear in categories related to problem-solving, real world, and effort.

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