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Abstract

Success in undergraduate biology courses relies upon a firm grounding in chemical principles. We sought to raise students' awareness of the connection between these two disciplines and to improve their understanding of each by carrying out a pilot project that integrated the curricula of Principles of Chemistry II (CHEM1212K) and Principles of Biology I (BIOL1107K) during the Fall 2016 semester. The study involved two course pairs: one section of each course delivered in the traditional non-integrated manner and a second pair of sections that were integrated across the chemistry and biology disciplines in both the scope and sequence of the content delivery. Both integrated and non-integrated sections were taught by the same instructors, who have expertise in both chemistry and biology to ensure a full understanding of both courses' content. Attitudinal surveys administered at the beginning and end of the semester showed that students in the integrated BIOL/CHEM section of our pilot study appreciated the delivery of an integrated curriculum and improved their awareness of the connections between the two disciplines. End-of-course assessments of topic mastery demonstrated improvements in the integrated students' capacity to understand and apply both biology and chemistry topics compared to students in the non-integrated sections.

Keywords

integrated curriculum, interdisciplinary, chemistry, biology, integrative learning

Enhancing Interdisciplinary Attitudes and Achievement via Integrated Biology and Chemistry Curriculum

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Abstract: Success in undergraduate biology courses relies upon a firm grounding in chemical principles. We sought to raise students' awareness of the connection between these two disciplines and to improve their understanding of each by carrying out a pilot project that integrated the curricula of Principles of Chemistry II (CHEM1212K) and Principles of Biology I (BIOL1107K) during the Fall 2016 semester. The study involved two course pairs: one section of each course delivered in the traditional non-integrated manner and a second pair of sections that were integrated across the chemistry and biology disciplines in both the scope and sequence of the content delivery. Both integrated and non-integrated sections were taught by the same instructors, who have expertise in both chemistry and biology to ensure a full understanding of both courses' content. Attitudinal surveys administered at the beginning and end of the semester showed that students in the integrated BIOL/CHEM section of our pilot study appreciated the delivery of an integrated curriculum and improved their awareness of the connections between the two disciplines. End-of-course assessments of topic mastery demonstrated improvements in the integrated students' capacity to understand and apply both biology and chemistry topics compared to students in the non-integrated sections.

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Introduction

The increasing interconnectedness and globalization of 21st century culture combined with the expanding body of knowledge about the natural world poses a challenge for both undergraduate students, who are expected to navigate these trends while mastering an increasing collection of facts and skills, and the faculty and administrators who educate and support them on the path to graduation. Two movements of particular significance in higher education – and with major implications for each of these parties – advocate for change from the traditional "stovepipe" set of discrete courses to those in which curricula are integrated across the college. Such programs aim to make course content more relevant while preparing students to solve complex problems that relate across different areas of study. The first movement draws on a growing collection of evidence showing that undergraduate research experiences enhance lasting learning, and in STEM fields, also enhance student interest in STEM careers (Awong-Taylor, 2016; Laursen, 2010; Lopatto, 2007, 2009; National Science Council, 2003).

In the second movement, an equally compelling argument has also been made that integrative learning across multiple disciplines in the humanities and social sciences, as well as STEM, also enhances lasting learning, perhaps even more so than undergraduate research experiences (Newell, 2010; Pursell, 2009; Ulsh, 2009; Van Hecke, 2002; Wolfson, 1998). For many working in higher education, the goals exemplified by these two movements may seem intuitively appropriate but, in practice, present significant administrative and instructional challenges that inhibit widespread implementation. In addition, limited resources coupled with myriad compelling and competing demands make implementation much more challenging for large public institutions than for highly competitive, well-funded schools.

The project we describe in this paper was carried out at Georgia Gwinnett College, a 4-year public college in the University System of Georgia with an enrollment of over 12,000 students and an open-access (non-competitive) admissions policy. Biology is one of the most popular majors and serves as a gateway for many of our graduates to careers in health and exercise science, government and industry, as well as graduate study in biological, biochemical, or environmental science. A common challenge for incoming Biology majors is the depth of understanding of fundamental chemical principles that is required to truly master the concepts presented in BIOL1107K (Principles of Biology I), a foundational 4-credit lecture/lab course that provides majors with an introduction to cell biology and biochemistry. We therefore targeted integrative learning in biology and chemistry by intentionally pairing this course with CHEM1212K (Principles of Chemistry II), a 4-credit lecture/lab course that constitutes the second semester of the general chemistry curriculum and has a general focus on quantitative applications of chemical concepts. Our intent was not just to improve our students' mastery of chemical and biological principles but also to present the courses' content in a way that clarified their interdependence and mutual relevance. As our students are non-competitive for admissions purposes, it was our expectation that they would substantially benefit from atypical instructional approaches designed to enhance learning and develop persistence.

Methods

Course Structure and Population

Four separate course sections for this study were established during the Fall 2016 semester: one section of BIOL1107K into which students freely enrolled, one section of CHEM1212K that was similarly open for normal student enrollment, and one section each of BIOL1107K and CHEM1212K in which we recruited student volunteers to enroll simultaneously, forming a cohort of students enrolled together in the integrated BIOL/CHEM sections. The only requirement for inclusion in the integrated courses was that students meet all course pre-requisites. Students in the non-integrated sections enrolled at random based on individual preference for schedule and/or instructor.

The experimental BIOL/CHEM schedule consisted of three-hour morning lectures in biology (Mondays) and chemistry (Wednesdays) with Monday and Wednesday afternoon blocks reserved for each subject's corresponding labs. To minimize variation in course schedule between the control and experimental groups, each of the non-integrated control sections similarly comprised two weekly blocks of three hours each to cover the respective biology or chemistry lecture and lab sessions. The same instructors led both the integrated and non-integrated class sections to eliminate variation in instructor efficacy and style; an experienced biochemistry instructor (Dr. Huey) taught the biology content for both the integrated and non-integrated BIOL1107K sections while an experienced biophysical chemist (Dr. Guo) taught the chemistry content for the integrated and non-integrated CHEM1212K sections.

Integrated Curriculum

To develop the integrated BIOL/CHEM sections, the instructors collaborated before and during the pilot semester to integrate the independent curricula used by the non-integrated sections (Table 1) into a synchronized plan

(Table 2) for use in the integrated sections. The color scheme used for Table 1 and Table 2 is the same for easier tracking of changes in the integrated curriculum. The intent was to coordinate in curricular space and time as many of the biology and chemistry concepts as possible to highlight the conceptual connections and mutually supporting application of shared biology and chemistry techniques and procedures to more complex, multi-dimensional problems.

Table 1. Regular curriculum for BIOL 1107K and CHEM 1212K. Shared contents are labelled in the same color.

Week	BIOL1107K	CHEM1212K
	Introduction to the Course	Introduction to the Course
1	Chapter 1: Life -- Chemical, Cellular, and Evolutionary Foundations	Chapter 9: Review Electron Configurations, Valence Electrons, Chemical Bonding
	Chapter 2: The Molecules of Life – Atoms and Bonding	Chapter 9: Lewis Dot Structures of Ionic Materials, Lewis Dot structures of Covalent Compounds
2		Chapter 9: Lewis Dot Structures of Covalent Compounds, Formal Charge, Resonance
3	Chapter 2: The Molecules of Life -- Water and Its Properties	Chapter 10: VSEPR and Molecular Shape
		Chapter 10: Predicting Polarity, Bonding Theories, Chapter 15: pH and pOH
	Chapter 2: The Molecules of Life -- Macromolecules	Chapter 11: Types of Intermolecular Forces
4	Chapter 3: Nucleic Acids and the Encoding of Biological Information	Chapter 11: Intermolecular Forces in Liquids and Gases, Phase Diagrams
5	Chapter 4: Translation	Chapter 12: Intermolecular Forces at Work in Liquids
	Chapter 4: Protein Structure	Chapter 13: Introduction to Kinetics, Rates of Reactions, Initial Rate Method
6	Unit 1 Test	Chapter 13: Integrated Rate Laws and Activation Energy
	Chapter 5: Organization of the Cell	Chapter 13: Reaction Mechanisms and Catalysts
7	Chapter 6: Overview of Metabolism	Chapter 14: Equilibrium and Equilibrium Constants
	Chapter 6: Chemical Reactions and Enzymes	Chapter 14: Determining Equilibrium Concentrations
8	Chapter 7: Glycolysis -- Overview	Chapter 14: Le Chatelier's Principle
	Chapter 7: Glycolysis -- Reactions	Chapter 15: Acid/Base Chemistry and Ka/Kb
9	Chapter 7: Citric Acid Cycle	Chapter 15: Determining Concentration in Acid/Base Solutions using Ka or Kb
	Chapter 7: Electron Transport Chain	Chapter 15: Acid/base properties of Salts, Molecular Structure and Acid/Base Strength, Lewis Acid/Bases
10	Chapter 8: Photosynthesis	Chapter 16: Buffer Range and Buffer Capacity. Determining pH in Acid/Base Titrations
	Unit 2 Test	Chapter 16: Determining pH in Acid/Base Titrations
	Chapter 10: Cell Form and Function	Chapter 16: Ksp, and Complex Ion Equilibrium
11	Chapter 10: Cytoskeletal Elements	Chapter 17: Review of Enthalpy, Introduction to Entropy and How to Calculate It
	Chapter 11: Mitosis	Chapter 17: Gibbs Free Energy and How to Calculate It
12	Chapter 11: Meiosis	Chapter 17: Gibbs Free Energy in Nonstandard states and Relating Gibbs Free Energy to Equilibrium
	Chapter 12: DNA Replication	Chapter 18: Balancing Complex Redox Reactions and Galvanic Half Reactions/Cells
13	Chapter 14: Mutation	Chapter 18: Determining Cell Potentials, Relating Cell Potentials to Gibbs Free Energy and Equilibrium Constants

Table 2. Integrated curriculum for experimental sections. Shared contents are labelled in the same color.

Week	BIOL1107K	CHEM1212K
1	Introduction to the Course	Introduction to the Course
	Chapter 1: Life -- Chemical, Cellular, and Evolutionary Foundations	Chapter 9: Review Electron Configurations, Valence Electrons, Chemical Bonding
2	Chapter 2: The Molecules of Life – Atoms and Bonding	Chapter 9: Lewis Dot Structures of Ionic Materials, Lewis Dot structures of Covalent Compounds Chapter 9: Lewis Dot Structures of Covalent Compounds, Formal Charge, Resonance
3	Chapter 2: The Molecules of Life -- Water and Its Properties	Chapter 10: VSEPR and Molecular Shape Chapter 10: Predicting Polarity, Bonding Theories, Chapter 15: pH and pOH
4	Chapter 2: The Molecules of Life -- Macromolecules	Chapter 11: Types of Intermolecular Forces
	Chapter 3: Nucleic Acids and the Encoding of Biological Information	Chapter 11: Intermolecular Forces in Liquids and Gases, Phase Diagrams
5	Chapter 4: Translation	Chapter 12: Intermolecular Forces at Work in Liquids
	Chapter 4: Protein Structure	Chapter 14: Equilibrium and Equilibrium Constants
6	Unit 1 Test	Chapter 14: Determining Equilibrium Concentrations
	Chapter 5: Organization of the Cell	Chapter 14: Le Chatelier’s Principle
7	Chapter 10: Cell Form and Function	Chapter 15: Acid/Base Chemistry and Ka/Kb
	Chapter 10: Cytoskeletal Elements	Chapter 15: Determining Concentration in Acid/Base Solutions using Ka or Kb
8	Chapter 11: Mitosis	Chapter 15: Acid/base properties of Salts, Molecular Structure and Acid/Base Strength, Lewis Acid/Bases
	Chapter 11: Meiosis	Chapter 16: Buffer Range and Buffer Capacity. Determining pH in Acid/Base Titrations
9	Chapter 12: DNA Replication	Chapter 16: Determining pH in Acid/Base Titrations
	Chapter 14: Mutation	Chapter 16: Ksp, and Complex Ion Equilibrium
10	Unit 2 Test	Chapter 13: Introduction to Kinetics, Rates of Reactions, Initial Rate Method
11	Chapter 6: Overview of Metabolism	Chapter 13: Integrated Rate Laws and Activation Energy
	Chapter 6: Chemical Reactions and Enzymes	Chapter 13: Reaction Mechanisms and Catalysts
12	Chapter 7: Glycolysis -- Overview	Chapter 17: Review of Enthalpy, Introduction to Entropy and How to Calculate It
	Chapter 7: Glycolysis -- Reactions	Chapter 17: Gibbs Free Energy and How to Calculate It
	Chapter 7: Citric Acid Cycle	Chapter 17: Gibbs Free Energy in Nonstandard states and Relating Gibbs Free Energy to Equilibrium
13	Chapter 7: Electron Transport Chain	Chapter 18: Balancing Complex Redox Reactions and Galvanic Half Reactions/Cells
	Chapter 8: Photosynthesis	Chapter 18: Determining Cell Potentials, Relating Cell Potentials to Gibbs Free Energy and Equilibrium Constants

Survey and Instrument Analysis

Using Institutional Review Board (IRB) approved project documents, we collected both attitude and performance data for all students enrolled in the integrated and non-integrated sections. For the attitude surveys, four-level Likert-scaled attitudinal surveys were used to collect data at the beginning and the end of the semester for all the participants. Demographic surveys were also given to better understand the profiles of students involved. In the twenty-question attitudinal survey, we assessed students' attitudes towards 1) biology, 2) chemistry, 3) integrated curriculum vs. regular curriculum, and 4) forming a biology-chemistry learning community with the same group of students in two courses. In addition, the attitudinal survey examined students' confidence in applying chemistry concepts, biology concepts, and recognizing the connection between chemistry and biology.

Student performance data were collected via pre- and post-assessments of biology, chemistry, and integrated biology-chemistry concepts and problems. Results were reported to the project coordinator (Dr. Pursell), who compiled and analyzed students' performance assessment, attitudinal, and demographic surveys. The project coordinator was not involved in teaching control or experimental sections; conversely, the course instructors were not involved in collecting attitudinal or demographic survey data and did not have access to these data until after the semester had concluded. The results from the surveys are reported under "Attitudinal Survey" in the Results section.

Pre- and Post-Assessment Analysis

Both the control and experimental sections took the same common content assessment at the beginning (pre-assessment) and the end of the semester (post-assessment), and assessments were evaluated by the instructors using a common rubric. Aside from questions focusing on biology and chemistry as two separate subjects, there are integrated assessment questions requiring the application of both biology and chemistry concepts. These integrated assessment questions focus on the shared contents in both courses and students in the control sections should have learned the concepts required to solve these problems. Student performance data on these assessments were both analyzed in aggregate using analysis of variance (ANOVA) and individually correlated with their incoming grade point average (GPA) using correlation analysis. Significance was assumed at $P < 0.05$ for each statistical test. The results for pre- and post-

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assessments are reported under “Effect of Integrated Curriculum on Chemistry” and “Effect of Integrated Curriculum on Biology” in the Results section.

Results

Attitudinal Survey

We examined student attitudes through survey questions to which students responded using a 4-point Likert scale (strongly agree=1, strongly disagree=4). The surveys were done at the beginning and again at the end of the course. Our particular interest was to then determine if individual students changed attitude about surveyed topics, presumably based on their experiences in either the integrated sections vs. the non-integrated sections. Preliminary data indicates several findings worth pursuing in subsequent iterations of the study.

Students in the integrated and non-integrated sections reported enjoying science, biology, and chemistry slightly less at the end of the semester than they did at the beginning of the semester. In terms of persistence, this is a potentially positive finding as students did not significantly change their reported enjoyment level in these topics after completing a rigorous semester, while nation-wide many first-year STEM students' experience in STEM courses is so daunting that they quit STEM and seek majors in non-STEM disciplines (President's Council of Advisors on Science and Technology, 2012; Seymour, 2000; Tobias, 1990). At an open-access institution such as ours, first year STEM students are especially vulnerable to the challenges of a rigorous academic program because they most likely have not experienced such a program in their pre-college academic preparation.

The integrated section had a stronger preference for taking biology and chemistry as integrated courses after completing the semester than they did at the beginning of the semester, indicating their perceived value with the integration. On the other hand, students in the non-integrated sections had a stronger preference for separate courses at the end of the semester.

The integrated section and the non-integrated biology section thought they improved their ability to apply specific biology and chemistry concepts by the end of the semester. Compared to the beginning of the semester, the non-integrated chemistry section reported less ability to apply both biology and chemistry topics, which was not unexpected since many of these students in the non-integrated chemistry section had not or will not take any biology courses during their college career.

Concerning the necessity of applying chemistry concepts in order to apply biology concepts, all three sections agreed with this necessity both at the beginning of the semester and again at the end of the semester. However, concerning the necessity of applying biology concepts in order to apply chemistry concepts, all three sections strengthened in their agreement from the beginning of the semester to the end of the semester that biology concepts are not necessary to applying chemistry concepts. This results implies that students believe chemistry supports biology, but not the other way around. In thinking about this finding, perhaps previous student experience in chemistry in high school and college has been with very traditional chemistry curriculum and instruction, which has been very slow in integrating biological applications of chemical concepts. Conversely, for many years, the biology community has incorporated the concepts of molecules, reactions, and energy, even at the introductory level, when broaching topics such as photosynthesis, respiration, and DNA reproductive processes. As such, students in biology are accustomed to viewing biological topics through the lens of chemical concepts while the converse is not so for students of chemistry viewing chemistry topics through the lens of biological concepts.

All students had virtually no change from beginning to end of semester in either their preference for study groups with classmates or preference for lecture vs. active learning environments. For pre- to post, students maintained a neutral preference (neither favor nor oppose) for study groups and preferred to have lecture rather than active learning. Colleagues at our college teaching introductory STEM courses with active learning techniques have also have noted this student preference for lecture. We surmise this lecture preference of introductory students is twofold: 1) it is what they are accustomed to from high school and 2) they prefer that instructors "tell them exactly what they need to know for the test," which students translate to lecture, rather than having to actively work to figure out for themselves what they need to learn in the course.

Effect of Integrated Curriculum on Chemistry

The Integrated BIOL1107K/CHEM1212K (N=10) and the chemistry control (N=23) sections were investigated to understand the effect of the integrated curriculum on understanding chemistry concepts. Because very few of the chemistry control section students were concurrently taking BIOL1107K

(N=2), we report the results from the chemistry control population as a whole and do not distinguish among students' prior or current biology experience.

The average percentage scores of CHEM1212K pre- and post-assessments were higher for the control chemistry section compared to the integrated section (Table 3). These students also had higher incoming CHEM 1211K grades and a higher overall GPA, possibly reflecting a firmer prior knowledge base in chemistry and stronger mathematical skills. Conversely, the integrated students demonstrated a higher average percentage score compared to Control CHEM1212K on the questions targeting shared content in both biology and chemistry in the pre- and post-assessments taken by all students; however, the difference was not judged to be significant (P = 0.16, Table 3). To eliminate the effect of insufficient exposure to interdisciplinary problems, both Integrated BIOL1107K/CHEM1212K and Control CHEM1212K sections had multiple interdisciplinary problems embedded in the curriculum throughout the semester. As all the integrated assessment questions focus on the shared contents in both courses, students in both the control and integrated sections had access to the knowledge and resources required to solve these problems.

Table 3. Student profiles of integrated and chemistry control sections.

	Student Population	
	Integrated BIOL1107K/CHEM1212K **N = 10**	**Control CHEM1212K** **N = 23**
Incoming GPA	3.07 ± 0.60	3.42 ± 0.42
CHEM1211K final grade, grade points earned	3.09 ± 0.83	3.35 ± 0.78
CHEM1212K final grade, grade points earned	2.70 ± 1.06	3.09 ± 0.85
CHEM Pre-Assessment (%)	2.1 ± 3.7	2.7 ± 3.2
CHEM Post-Assessment (%)	54.5 ± 20.9	59.8 ± 20.1
Integrated Assessment Score (%)	38.7 ± 20.9	31.3 ± 18.6

Note: significance was assumed at $P < 0.05$.

Effect of Integrated Curriculum on Biology

The study design yielded three populations of students among the two sections (integrated and non-integrated) of BIOL1107K: 1) the Integrated BIOL1107K/CHEM1212K cohort (N=10); 2) students enrolled in the non-integrated BIOL1107K section that were simultaneously taking a separate CHEM 1212K section ("Control BIOL1107K+ CHEM1212K" group, N=10); 3) students enrolled in the non-integrated BIOL1107K section that did not take CHEM1212K at all during the Fall 2016 semester ("Control BIOL1107K-CHEM1212K" group N=10, Table 4). Analysis of variance (ANOVA) among the three populations of students revealed no significant difference in the students' GPA prior to the Fall 2016 semester (Table 4). Scores on the BIOL1107K pre- and post-assessments and on the standard BIOL1107K End-of-Course (EOC) Assessment tended to be higher for the Integrated course students compared to the control BIOL1107K groups, but these differences were not judged to be significant ($P > 0.05$ for each parameter). There were also no significant differences among the groups' average improvement in their BIOL1107K pre-assessment scores over the course of the semester (Δ BIOL Assessment), the students' final BIOL1107K grades, or their final CHEM1212K grades earned at the end of the semester, although each of these parameters again tended to be higher for the Integrated group compared to the control BIOL1107K students (Table 4). Students in the Integrated section were better able to correctly answer the biochemistry free-response questions ("Integrated Assessment" Table 4) at the end of the semester compared to BIOL1107K students either concurrently taking a non-integrated CHEM1212K course or not enrolled in CHEM1212K at all during Fall 2016 ($P = 0.008$). The Integrated group also performed significantly better on that component of the BIOL1107K EOC Assessment that dealt specifically with chemical and biochemical topics ("BIOL1107K EOC Assessment Score – Chemistry Questions", Table 4) than did their control counterparts ($P = 0.038$). Previous studies with small sample sizes support the significance of our results. (Pursell, 2017; Ruxton, 2006).

The correlation among each of these variables in the three populations of BIOL1107K students was examined (Figure 1). Incoming GPA in all populations examined was positively and significantly correlated with final course grades for both BIOL1107K (Figure 1a) and CHEM1212K. Similar correlations were observed between students' GPA and scores on the BIOL1107K EOC Assessment (Figure 1b) and student performance on the chemistry-specific questions on the BIOL1107K EOC Assessment (Figure 1d). However, there was no significant correlation between student GPA and improvement on the BIOL1107K EOC post-assessment compared to the pre-assessment administered at the beginning of the semester within the Integrated group (Figure 1c). This observation suggests that students' academic performance prior to enrolling in the BIOL1107K/CHEM1212K integrated course did not pre-determine their ability to improve their overall understanding of biology topics. In contrast, both control groups of BIOL1107K students demonstrated a significant positive correlation between their GPA at the beginning of the semester and the differential between their biology pre- and post-test scores (Figure 1c).

Table 4. Student profiles of integrated and biology control sections.

	Student Population		
	Integrated BIOL1107K/CHEM1212K	**Control BIOL1107K + CHEM1212K**	**Control BIOL1107K - CHEM1212K**
	N = 10	**N = 10**	**N = 10**
Incoming GPA	3.07 ± 0.60	3.02 ± 0.39	2.83 ± 0.64
BIOL1107K final grade, grade points earned	2.70 ± 0.95	2.60 ± 1.07	2.50 ± 1.08
CHEM1212K final grade, grade points earned	2.70 ± 1.06	2.57 ± 0.53	N/A[2]
BIOL Pre-Assessment, %	42.6 ± 19.2	35.3 ± 10.2	28.2 ± 4.9
BIOL Post-Assessment, %	71.1 ± 18.6	66.7 ± 18.1	58.8 ± 19.3
Δ BIOL Assessment, %	32.7 ± 8.99	19.8 ± 12.7	22.0 ± 13.7
CHEM Pre-Assessment	1.3 ± 2.2	N/A[1]	N/A[2]
CHEM Post-Assessment	32.7 ± 12.5	N/A[1]	N/A[2]
Δ CHEM Assessment	30.9 ± 13.5	N/A[1]	N/A[2]
Integrated Assessment Score	12.0 ± 6.5*	6.0 ± 4.7	4.2 ± 4.6
BIOL1107K EOC Assessment Score, %	70.2 ± 16.6	63.4 ± 15.2	56.2 ± 17.0
BIOL1107K EOC Assessment Score – Chemistry Questions, %	71.0 ± 15.2**	60.6 ± 14.9	52.9 ± 15.7

Note: significance was assumed at $P < 0.05$.

1 These students were concurrently enrolled in a non-integrated section of CHEM1212K during the Fall 2016 semester and did not take the CHEM1212K Pre- or Post-Assessments.

2 These students were not enrolled in CHEM1212K at all during the Fall 2016 semester and did not take the CHEM1212K Pre- or Post-Assessments.

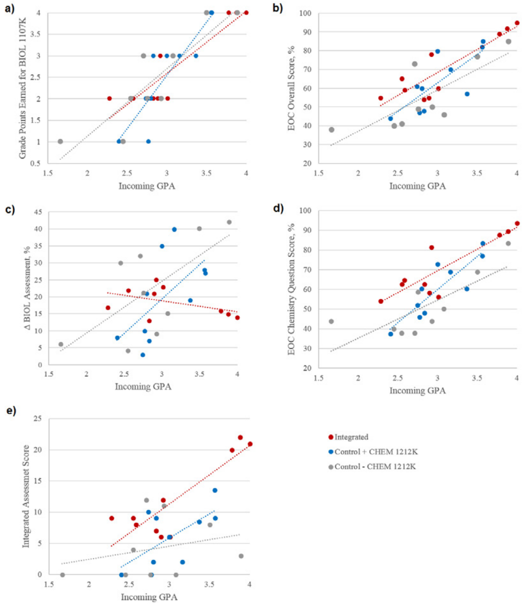
* Significantly different from control groups, $P = 0.008$

** Significantly different from control groups, $P = 0.038$

The correlation between GPA and performance on the Integrated

Assessment questions was also determined among the three BIOL1107K student groups. Both Integrated BIOL1107K/CHEM1212K students and students taking non-integrated BIOL1107K and CHEM1212K separately showed a significant positive correlation between these parameters, with the Integrated section showing a significantly higher level of achievement on the Integrated Assessment questions overall (Figure 1e and above). In contrast, the BIOL1107K students who were not concurrently enrolled in CHEM1212K during Fall 2016 showed no correlation between their incoming GPA and their performance on the Integrated Assessment questions.

Figure 1. Correlation analyses of a) BIOL1107K GPA vs. incoming GPA, b) EOC overall score vs. incoming GPA, c) ΔBIOL1107K Assessment score vs. incoming GPA, d) EOC Chemistry questions score vs. incoming GPA, and e) Integrated Assessment score vs. incoming GPA for three populations of BIOL1107K students.



Conclusions

Our study assesses the effect of integrated curriculum on students' attitudes towards learning two courses as an integrated course, their conceptual understanding of contents in both disciplines, and the awareness of connection between the two disciplines. Even though the total number of students from the one-semester study is small, there are several noteworthy indications in this initial set of data. Our attitudinal survey shows that the integrated curriculum can improve students' preference in taking the two courses as an integrated course after the completion of the course, which indicates their perceived value of the integration. The attitudinal survey also shows that integrated curriculum is effective in improving students' ability to apply both biology and chemistry topics. This is demonstrated by better performance on integrated assessment questions requiring application of knowledge in both disciplines in the integrated section over biology control section. The difference between integrated and chemistry control sections was not statistically significant, which would require further observation for firm conclusion. In terms of recognizing the connection between the two disciplines, students in all sections acknowledge that chemistry is fundamental for proper application of biology principles, especially the biology topics that have a chemistry aspect. This is illustrated by better performance on components of the BIOL1107K EOC Assessment that dealt specifically with chemical and biochemical topics in the integrated section.

This project is currently continuing for the Spring and Summer 2017 semesters, during which the same course structure has been implemented with respect to schedule and instructors; we will also introduce two integrated laboratory projects targeting the shared content in both courses. It is our hope that the trends we have observed in this pilot study will be confirmed and will be of use in re-designing STEM curricula within our institution.

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