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IMPLEMENTATION OF AN UNDERGRADUATE INTEGRATED BIOLOGY & CHEMISTRY (IBC) COURSE

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Abstract

An integrated biology and chemistry (iBC) course for freshmen college students was developed in University of Delaware. This course will prepare students to (1) become interdisciplinary thinkers in the field of biology and (2) collaboratively work with others from multiple disciplines in the future. This study documented and described the implementation of the course in terms of its physical environment, course format and scheduling, teaching team, and course content. The challenges in the implementation and how they were addressed were also described. The information gathered from reading literature, classroom observations, and interviews were used to carry out the purpose of this study. The course is taught in the Interdisciplinary Sciences Learning Laboratories of the university. The iBC is composed of lectures, laboratories, studio sessions, and workshops and is taught by the faculty from the biology and chemistry departments. In addition, the teaching team involved in the delivery of the course is composed of the preceptors, the graduate teaching assistants, and studio fellows who facilitate the laboratory and studio sessions. In addressing the challenge of integrating the topics in both disciplines, the topics and laboratory activities in both disciplines were aligned. The iBC can be used as a model for other higher education institutions who wish to implement an integrated biology course.

Keywords

Integrated Biology and Chemistry, Integration, Interdisciplinary Research, New Biology, Undergraduate Science Education

1. Introduction

Undergraduate science education is under continuous reforms and constant dynamisms. These pressing educational reforms emerged from the notion that future biologists are faced with complex and challenging problems that require them to draw on concepts from various disciplines. National agencies advocate a “New Biology” that entails greater collaboration with chemists. This aims to integrate biology into different scientific disciplines such as chemistry, physics, mathematics, and engineering. As a consequence, a research community that can adapt to the changing scientific and societal problems is achieved (National Research Council, 2009).

This novel approach in science education is embedded in Bio2010 that provides goals and objectives in developing a new curriculum in biology. This advocacy aims to expose undergraduate students to an interdisciplinary research that would prepare them to work collaboratively with others from multiple disciplines. Furthermore, it identifies the essential skills needed by the students in coping with this challenge. These include scientific knowledge, practice with experimental design, quantitative abilities, and communication skills (National Research Council, Committee on Undergraduate Biology Education to Prepare Research Scientists for the 21st Century, 2003).

Over the past decades, the teaching of biology and chemistry is heavily compartmentalized. Each course was discipline-specific. Despite this, students are still expected to combine their learnings from one discipline to another (Murray, Atkinson, Gilbert, & Kruchten, 2014). To surmount this challenge, major educational reforms, particularly in undergraduate biology education, have emerged. Different academic institutions facilitated the revisiting and reforming of their respective biology curriculum. The National Academy of Sciences called it the “New Biology”. It emphasized, *“The essence of the New Biology, as defined by the committee, is integration - re-integration of the many sub-disciplines of biology, and the integration into biology of physicists, chemists, computer scientists, engineers, and mathematicians to create a research community with the capacity to tackle a broad range of scientific and societal problems”* (National Research Council, 2009).

Several undertakings show the great potential that this educational change can offer. For example, an Accelerated Integrated Science Sequence (AISS) course, which interspersed Biology, Chemistry, and Physics, was implemented for freshmen college students. The implementation of the course was successful in terms of having students learn to think in an interdisciplinary manner (Purvis-Roberts et al., 2009). It further resulted in a higher rate of students who continued the course in the next semester of implementation. In another study, first year college students who were enrolled in an integrated science course for undergraduate STEM majors have provided a way to build their interdisciplinary skills (Gentile et al., 2012). Their preliminary observations suggest that students who were exposed to an integrated course have begun research earlier and were taking more math and sciences courses.

The integration of science disciplines such as biology and chemistry also develop the students' critical and analytical thinking. For instance, a STEAM (Science, Technology, Engineering, Art, and Mathematics) approach was integrated in a chemistry class. This allowed students to challenge their critical thinking and thus, develop their 21st century skills (Hadinugrahaningsih, Rahmawati, & Ridwan, 2017). In another study, Hiong and Osman (2015) purported that an interdisciplinary approach of teaching biology develops students' 21st century skills. It also allows students to master biological knowledge and be well-versed of other sub-discipline skills.

These benefits of implementing integration across biology and chemistry in an undergraduate science education are auspicious. The curriculum changes will not only expose the students to early training in interdisciplinary thinking but will also prepare them to become future biologists equipped with indispensable skills ready to work collaboratively with others from various disciplines.

In the light of this paradigm shift, the University of Delaware, through its Interdisciplinary Sciences Learning Laboratories (ISLL), has introduced an integrated biology course that provides students with a novel science learning experience. Using the information gathered from reading literature, classroom observations, and interviews, the implementation of an integrated biology and chemistry course is described. Furthermore, the approaches used to address the challenges encountered in the implementation are also discussed briefly.

2. Research Objectives

United States is a leader in scientific research and education. American institutions have championed educational reforms that provided undergraduate students opportunities to develop scientific and critical thinking skills essential to their future careers. The main objective of this study is to document how an undergraduate integrated biology and chemistry course was implemented. Specifically, this study determined how the following components of the course were implemented:

1. Physical environment;
2. Course format and scheduling;
3. The teaching team; and
4. Course content.

Furthermore, this study also described how the challenges in the implementation were addressed.

3. Methodology

This is a descriptive type of study that involved gathering of information using classroom observations, interviews, and examination of syllabi. The following methods were taken to achieve the research objectives:

- a. *Classroom observations* were conducted in iBC classes. These were done to describe what transpired in an iBC class.
- b. *Interviews* of the members of the iBC teaching team were conducted. The information gathered from the interviews were used to document and describe the implementation of the course.
- c. *Examination of the course syllabi* was also carried out. This was conducted to determine how the biology concepts were aligned with the chemistry concepts. In addition, the overlapping concepts between the two disciplines were also identified.

4. Results

To describe how the iBC course was implemented the components of the course, e.g. physical environment, course format and scheduling, teaching team, and course content, were elaborated in the succeeding paragraphs.

4.1 Physical Environment in an iBC Course

To cater the need for integration, the teaching, learning, and research in an iBC course takes place in the Dupont's Interdisciplinary Sciences Learning Laboratories (ISLL) located at the university's Patrick T. Harker Interdisciplinary Science and Engineering (ISE) Laboratory (Figure 1). The ISLL is equipped with facilities and technology suited for achieving the purpose of the course. These include wide learning space, studio classrooms, and laboratories.



Figure 1: *The Interdisciplinary Science and Learning Laboratories is housed in the University's ISE Lab*

The Problem-based Learning (PBL) Studio is a unique classroom where collaborative learning is made possible (Figure 2). The studio has mobile node chairs that allow students to move freely and work with others. The walls of the classroom are writable. This is helpful for students during PBL activities where they can organize their ideas through concept maps and diagrams by just writing on the wall. Monitors and projectors are also installed in the room. The studio is spacious and can accommodate 48 students. This class population is designed for an integrated course. The Learning Space is an area in the ISLL equipped with tables and chairs where students, faculty, teaching assistants, peer-led team leaders, preceptors and those that are involved in the course can meet for lectures, discussions, and tutorials (Figure 3). The Saddleback Labs are wet labs accoutered with fume hoods, benches, microscopes, iPads, and other equipment (Figure 4). There are two wet labs for each studio – one for biology and one for chemistry.



Figure 2: *The Problem-based Learning Studio is where studio sessions and lectures are conducted*



Figure 3: *The Learning Space is a place where students, faculty, and preceptors meet for lecture and discussion outside the class time*



Figure 4: *The Saddleback Laboratory is composed of both the biology and chemistry wet labs. These labs are adjacent to the studio room*

4.2 Course Format and Scheduling

The iBC course is offered during the Fall and Spring semesters of every school year (Table 1). Freshmen students who are enrolled in BISC207 are also enrolled in CHEM107 during the fall semester. In the same manner, those who are enrolled in BISC208 are also enrolled in CHEM108 during the spring semester. Each course is given four credits.

Table 1: iBC Course Offerings per Semester

Course	Fall	Spring
Biology	BISC 207	BISC 208
Chemistry	CHEM 107*	CHEM 108*

*Co-requisite of Biology

The course scheduling in an iBC course is uniquely different from a non-integrated biology course. Both biology and chemistry is composed of class lecture, studio session, and laboratory with an extra workshop session in chemistry (Table 2). Each component, except for the workshop, is recited twice a week. The class lecture in Biology is allotted an hour and 55 minutes, while the studio session is recited for an hour and 20 minutes each week. Both the lecture and studio take place at the same time schedule for each session. Most of the time, the studio session incorporates activities from the pre- and post-lab work. During this session, students are given studio assignments related to what they are doing in the laboratory. These may be in a form of worksheets, pre-lab quiz, or activities that would develop their skills in scientific writing, data analysis, and quantitative reasoning. It can also be an avenue where students present the results and discussions of their experiment through a poster. Also, this session can be used to review and augment concepts discussed during the biology and chemistry lectures.

Table 2: iBC Class Schedule in an Honors Section

Component	Session 1	Session 2	Total Time Allotment per week
BISC Lecture	55 min	55 min	1 hr 50 min
BISC Studio	40 min	40 min	1 hr 20 min
BISC Lab	1 hr 55 min ^a	1 hr 55 min ^b	3 hrs 50 min
CHEM Lab	1 hr 55 min ^b	1 hr 55 min ^a	3 hrs 50 min
CHEM Lecture*	1 hr 55 min	1 hr 20 min	3 hrs 15 min
CHEM Workshop	2 hrs		2 hrs

^aFirst sub-section of the class

^bSecond sub-section of the class

*Incorporates the studio sessions

On the other hand, the set-up for the lab is different from the lecture and studio. Laboratory is recited twice a week for an hour and 55 minutes for each section. Each section is composed of 48 students. During the lab, these students are divided into two sub-sections with 24 students for each sub-section. The first sub-section will perform the biology lab while the second sub-section will perform the chemistry lab on a different time schedule. Conversely, in a different time schedule of the week, the first sub-section who did the biology lab will now do the chemistry lab while the second sub-section who previously did the chemistry lab will now do the biology lab. In this manner, students from each sub-section will have different time schedule for the biology and chemistry lab works.

In addition to the above components, a workshop session in chemistry is required for students to attend. In this workshop, students are actively engaged in understanding chemistry concepts before it is discussed in the class lecture. With the session led by an undergraduate peer facilitator, they can ask questions and discuss with peers about their understanding of the current topic in the course.

4.3 The Teaching Team in Integrated Biology and Chemistry

Unlike the non-integrated biology course where only the teacher and the students are mostly involved, there are other important persons in iBC who play important roles during class sessions (Figure 5) (Interdisciplinary Science Learning Laboratories, 2017).

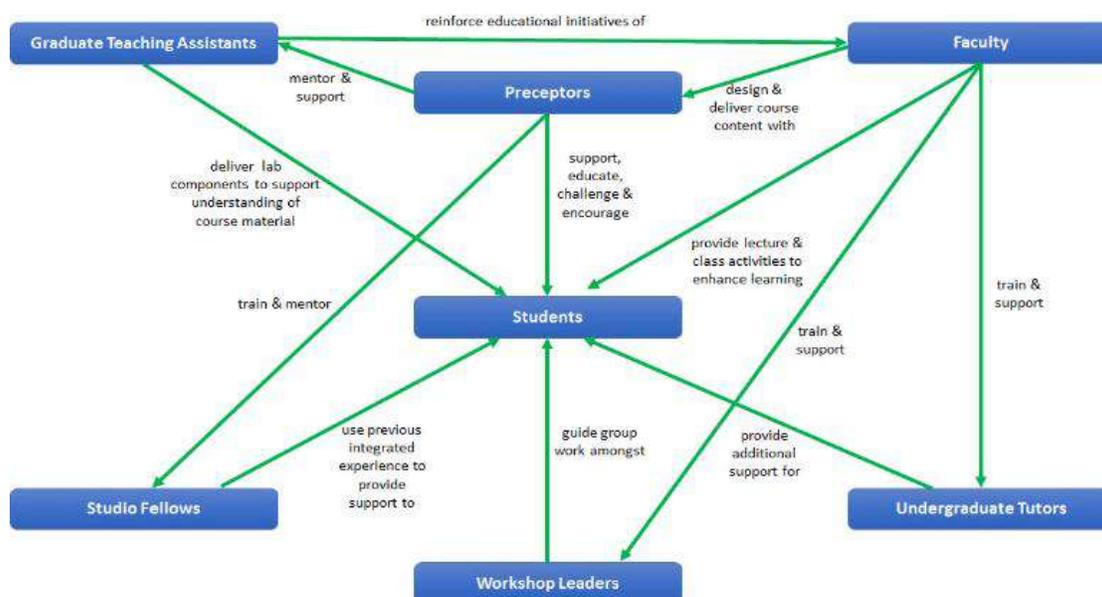


Figure 5: *The Interdependent Teaching Team in iBC*

Preceptors are full-time scientists working together with the faculty, studio fellows, and graduate teaching assistants in developing the curricula for the laboratory and studio sessions. They are directly involved in engaging students during the laboratory activities and studio sessions. A preceptor serves as an advisor to students during their problem-based learning or small group activities. In addition, preceptors essentially aid students in seeing the connections between biology and chemistry since they are involved in the planning, as well as in the implementation of the lecture and laboratory parts of both the biology and chemistry course. Furthermore, as a resource for students, preceptors make themselves available to students as they prepare for the week's scheduled laboratory activities, and guide them as they analyze and present their data from the experiments. Moreover, aside from facilitating studio and laboratory activities, preceptors mentor and support graduate teaching assistants and studio fellows as they work with them in developing the course curricula.

The role of preceptors is different from the faculty teaching the course. The faculty is responsible for preparing the lecture for each course. They are also tasked to give students their grade for the course. This responsibility is not given to the preceptors. In other words, preceptors serve as an ally for students where they can run to whenever they have problems with the course. Along with the preceptors, studio fellows used their previous experience in the course to provide support to the students. Specifically, studio fellows help facilitates activities that improve students' understanding of the lectures and laboratories. Alternatively, they assist students prepare for their laboratory experiments by helping them apply concepts from lectures to laboratory experiments. Studio fellows are undergraduates who come from various majors who have already taken the course. They are contracted on a semester basis to take this role based on a variety of criteria such as their grades, previous iBC experience, and excellent communication skills.

Other roles that are important in the iBC course are the graduate teaching assistants and workshop leaders. The teaching assistants are responsible for delivering the laboratory component so that students can understand the course materials. Additionally, they are also responsible for developing the laboratory curriculum together with the preceptors to help reinforce the lecture component of the course. Lastly, the workshop leaders are undergraduate peer facilitators responsible for facilitating a highly active and engaging workshop session. The

workshop leaders help students learn the concepts before they are introduced in class or help them augment or refine their understanding of current topics.

In summary, these people comprise the collaborative teaching team of the integrated biology and chemistry course. It should be noted that each role is not mutually exclusive. Instead, they are synergistic that support and assist one another to achieve the ultimate goal of the course.

4.4 iBC Course Content

The content for the integrated biology and chemistry course is unique. The course highlights the overlapping concepts in both biology and chemistry. In this manner, students would be able to see and appreciate the connections between the two disciplines which is the purpose of this course.

The first semester biology component of this course covers the molecular basis of life, structure and functions of cells including the signal transduction pathways, energy transformations, classical Mendelian genetics, and the flow of information from DNA to RNA to proteins (Lavery, 2016). On the other hand, the second semester biology component includes the mechanisms of evolution, physiology of multicellular plants and animals, animal and plant anatomy, and the principles of ecology with emphasis on the biology of populations (Lavery, 2017). The laboratory component focuses on developing and testing hypotheses, analyzing data, and scientific writing. A topic outline that covers these concepts in Biology is found in Table 3.

Table 3: Biology Topics in an iBC Course

First Semester Biology	Second Semester Biology
Water and Carbon: The Chemical Basis of Life	Climate change
Protein Structure and Function	Natural Selection
Nucleic Acids and RNA	Mechanisms of microevolution
Carbohydrates, Lipid Membranes and the First Cells	Hardy-Weinberg Principle
Cell to Cell Interactions	Macroevolution
Energy and Enzymes: Introduction to Metabolism	Speciation and Species Concept
Cellular Respiration and Fermentation	Homeostasis
Photosynthesis	Internal Transport in Multicellular Organisms
The Cell Cycle and Mitosis	
Meiosis	Gas Exchange and Transport
Mendel and the Gene	Introduction to Ecological Concepts
DNA and the Gene: Synthesis and Repair	Community Ecology
Transcription, RNA Processing, and Translation	Population Ecology
Control of Gene Expression in Eukaryotes	
The Molecular Revolution, Biotechnology and Beyond	

The chemistry component of the course covers the different principles of chemistry with applications to biology and other life sciences. Specifically, the course details concepts that are summarized in Table 4 (Fajardo, 2016; Fajardo, 2017).

Table 4: *Chemistry Topics in an iBC Course*

First Semester Chemistry	Second Semester Chemistry
The Study of Chemistry	Periodic Trends
The Components of Matter	Hybridization
Chemical stoichiometry	Introduction to Organic Chemistry
Chemical Reactions in Solution	Intermolecular Forces of Liquids and Solids
Chemical Thermodynamics	Properties of Solutions
Light-Matter Interactions	Chemical Kinetics
The Quantum Mechanical Model and the Periodic Table	Gases and Kinetic Molecular Theory
Molecular Structure (Ionic & Covalent Bonding; Geometry & Polarity)	Chemical Equilibrium (Applications to Acids & Bases)
	Acid-Base Equilibria and Solubility Equilibria
	Entropy, Free Energy, and Equilibrium
	Electrochemistry

To augment students' understanding of these concepts and see how the concepts from biology are related to chemistry and vice versa, they are given series of laboratory activities where these are investigated. The preceptors and the graduate teaching assistants developed the curriculum for the laboratory component of the course. The majority of the laboratory activities emphasized developing students' inquiry skills where they design how to do the experiment and draw conclusions from their data. The results of their experiments are then communicated through poster presentations. The laboratory activities were also designed in such a way that the overlapping concepts in both disciplines are articulated (Figure 6). For instance, a laboratory experiment involved collecting water samples from local streams. These water samples were analyzed using biological tests such as identifying macroinvertebrates and coliforms and surveying microorganisms. The same water samples were used for chemical analysis using alkalinity test and Iron, Phosphorus, Organic Carbon analysis. Sometimes, students will work on a project that requires them to apply their knowledge from both disciplines. In cases where lab activities from each discipline are not that closely related, preceptors and TAs plan additional activities to make the connections between the concepts more obvious and clear.

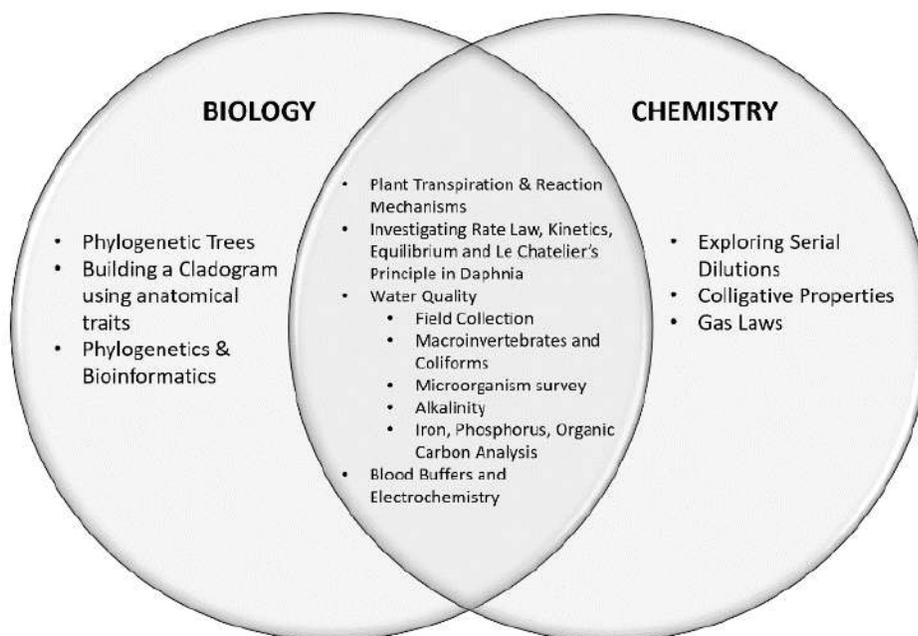


Figure 6: Venn diagram of laboratory activities showing the overlapping concepts in both disciplines

4.5 Addressing the Challenges in the Implementation

The objectives of the iBC course were to (1) develop an attitude of inquiry among students, (2) promote active learning in the classroom, and (3) emphasize interdisciplinarity through the integration of biology and chemistry. The course had provided avenues for students to develop their inquiry skills and higher order thinking such as problem-based learning during studio sessions, developing their own design of investigation in the laboratory, and presenting their results in a form of poster sessions. These also allowed students to be actively engaged in activities, both inside and outside the classroom, all throughout the course.

However, despite this success, the challenges in implementing this course were inevitable and needed to be addressed. One of which was how to measure the students higher order thinking. This is essential as it will provide the faculty and other members of the teaching team evidence that what they are doing and the activities that they have prepared were effective in achieving the purpose of the course. In addition, the course is also assessing the students' scope of knowledge and the depth of understanding of the concepts in both disciplines. One of the concerns arising from this is dealing with the misconceptions among the students. This was evident during poster presentations, for example, where students may have presented a well-

written output. However, when asked about the results and findings of their study, the faculty can see loopholes on students' answers, as well as their understanding of certain concepts. The workshop sessions can be used to address this issue. During this session, students' misconceptions can be corrected and what they do not understand will be addressed.

The alignment of course content in both disciplines also posed a challenge for the faculty teaching both courses. The major goal of this part of the implementation is how to make the topics integrated and seamless. The integration is not expected to be fully 100% because not all topics are related to each other. One of the practices the faculty teaching the course did before entails both biology and chemistry faculty teach a certain topic at the same time. In that sense, each faculty can discuss the biology or the chemistry aspect of the topic at the same time. Today, to fully maximize the extent of integration, the course made sure that the sequence of topics and laboratory activities in both disciplines are aligned. For example, if the biology component covers water quality analysis by looking at macroinvertebrates and coliforms, the chemistry component also covers water quality analysis by studying alkalinity. This is only a part of an effort to at least fully integrate the concepts between the two disciplines. At present, the teaching team is gearing towards aligning and integrating the lectures and the laboratory activities within each discipline. The integration of concepts should not only be between biology and chemistry but more importantly between the concepts learned in the laboratory and the lectures.

Abdella, Walczak, Kandl, & Schweinfus (2011) used a similar approach in an integrated chemistry and biology where chemistry topics are taught vis a vis the biology concepts. In this three-sequence course, chemistry concepts were taught sequentially from smaller to larger particles. On the other hand, the biological concepts were taught in parallel to the chemistry concepts. This approach allowed students to better appreciate the connection between the two disciplines.

Another major challenge involves developing the studio and laboratory activities that would ensure students to apply the different concepts from one discipline to another. These activities should explicitly show the "connections" between biology and chemistry which will help the students think in an interdisciplinary manner. To overcome this challenge, the studio and laboratory components of the course were designed in such a way that activities are not isolated and that they are interrelated to one another. For example, in a chemistry lab, students will have to extract active ingredients from sun screen and measure its ability to absorb light. In a biology

lab, students use the same materials to measure the ability of sun screen to protect the living cells from UV-induced damage. This is an example where students are given with a scientific problem and solve this problem in different ways using the concepts they have learned from biology and chemistry. In another example, students were given a project that involves producing fuel from plants. This requires them to use laboratory times from biology and chemistry and apply the knowledge they learned from both disciplines.

These kinds of activities are not usually observed in a standalone biology or chemistry classes where students must draw knowledge from one discipline and apply it to another. Thus, this makes the course unique to other introductory biology and chemistry courses. Based from these practices, it is evident that the implementation of the course was successful. However, it is also important to point out that there are still challenges that lie ahead. Addressing these challenges is necessary in improving the course.

5. Discussion

The initiative to make major reforms in the undergraduate biology education curriculum requires intensive effort, resources, teamwork, and collaboration from major key players. For example, prior to the implementation, the iBC course underwent several phases. It started from biology and chemistry faculty observing each other's class for two semesters. In this way, they would be able to share their observations on how to realign their courses in such a way that concepts from both disciplines are connected. It also allowed them to sequence their topics and create laboratory experiments suited to the purpose of the course. From here, faculty will write problem-based learning problems which will be used in both courses which are taught on the same semester.

One of the factors that made the implementation of the course possible was the support given by the university in providing a venue for the integration of biology and chemistry. The Interdisciplinary Sciences Learning Laboratories equipped with studio rooms, wet laboratories, and learning spaces made the classes conducive to learning. The PBL studio rooms were also made seamless with the adjacent laboratories. This kind of environment encourages students to become actively engaged in the learning process, which is one of the goals of the course.

The format of the course is also different from a standalone biology or chemistry course. In an integrated biology course, the class usually starts with a studio session for about 40 minutes. During this time, the preceptor reminds students of the outputs or tasks in biology and

chemistry that are due for the week. These include laboratory activities, concept maps and worksheets, and pre-lab activities. The preceptor proceeds by facilitating activities, such as simulations, that would augment students understanding of the concepts that will be covered in lectures and laboratories for the week. This will be followed by the lecture provided by the faculty.

As mentioned earlier, the iBC course is unique because of its purpose and the novel ways of attaining this purpose. One of the remarkable characteristics of iBC is the interdependent teaching team that comprises the faculty, preceptors, graduate teaching assistants, and studio fellows. This group of people performs each specific role but their function is not isolated from the others. The faculty works with the preceptors to deliver the desired course content while the graduate teaching assistants reinforce this initiative of the faculty. Both the preceptors and the graduate teaching assistants plan, develop, and deliver the studio activities and laboratory experiments. The studio fellows support the preceptors during the studio sessions while being trained and mentored by the latter. These people are essential to the success of the ultimate beneficiaries of the course – the students.

Another equally important factor that makes the course unique and successful is the emphasis of overlapping biology and chemistry concepts in the studio sessions and laboratory activities. As described, these components of the course are designed and implemented by the preceptors and graduate teaching assistants with the support from the studio fellows. During the studio sessions, preceptors provide background information about the biology and chemistry concepts to be investigated during the laboratory activities scheduled for that week. To illustrate, a class who will be doing an experiment on Equilibrium and Le Chatelier's Principle was given a simulation called Rules of Equilibrium Dice. During this activity, students used cups and dice to demonstrate what happens to reactants and products during an equilibrium and nonequilibrium state. A preceptor prepared an excel file that can be accessed by all the students and record the data they gathered. At the end of the activity, the preceptor showed a graph to the class based from the data the students recorded in real time. With this activity, students have a priori about this concept before doing the laboratory activity. This is essential as it would give students an understanding of the concepts and a better appreciation of its connection to the concepts discussed in the other discipline.

The university's iBC course has been in existence since 2013. It has served many students from various majors. Figure 7 shows the actual number of students enrolled in iBC (vs. non-integrated) during the fall and spring semesters since it started in the fall of 2013. The total number of students served by the course is 4,338 (Office of the University Registrar, 2017).

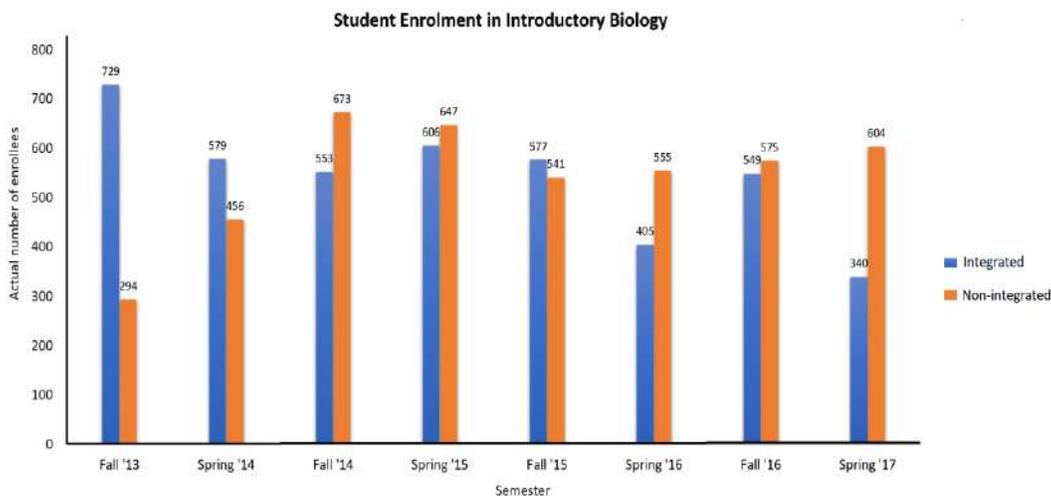


Figure 7: Actual number of students enrolled in the integrated and non-integrated biology from 2013 to 2017

The start of the implementation of the course received the most number of student enrollees. The number of enrollees in the integrated and nonintegrated biology is comparable in both the spring and fall semesters of 2015 and the fall of 2016. However, there was a decline in the number of enrollees in the integrated course during the fall of 2014, and the spring of 2016 and 2017. This decline can be attributed to several factors. It may be due to fewer majors who require students to take the integrated biology course. It could also be that students are only required to take one integrated course, e.g. BISC207/CHEM107, which is offered in the fall. It can also be assumed that the decline in numbers may be due to losing the students because of too much work to be done in the integrated course as compared to the nonintegrated but is given the same number of credits. This may indicate that there is a need to reassess the amount of work given to the students in an iBC course without compromising the purpose of the course.

Lastly, Figure 8 shows the distribution of majors that require their students to take an introductory biology (both integrated and nonintegrated) course from 2013 to 2017. The majors that mostly require students to take this course include Biological Sciences, Exercise Science, Neuroscience, and Pre-vet and Animal Biology (Office of the University Registrar, 2017).

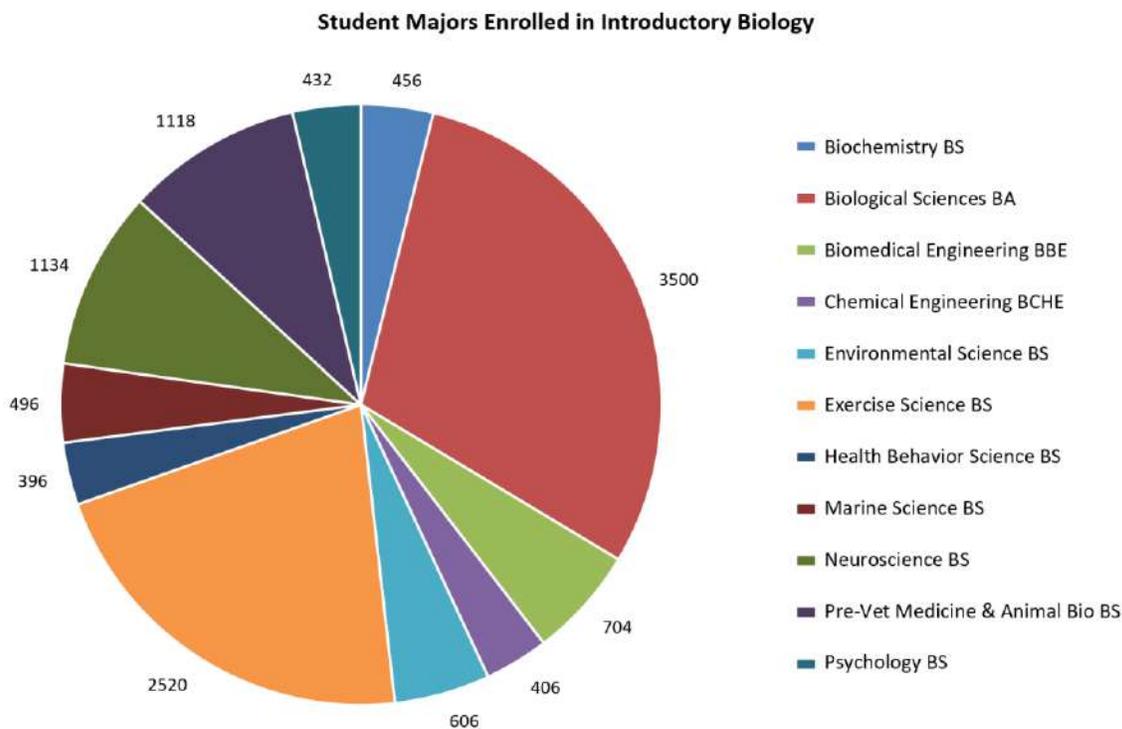


Figure 8: *Distribution of majors required to take introductory biology from 2013 to 2017*

6. Conclusions

The implementation of the integrated biology and chemistry course was successful. The topics from both disciplines were aligned properly. This was done by ensuring that the sequence of the topics and laboratory activities is parallel in both disciplines. However, the integration was only limited to integrating biology to chemistry and not with other sciences such as physics and mathematics. Nevertheless, the students who experienced the iBC course allowed them to develop their interdisciplinary thinking skills. Thus, this prepared them to work collaboratively with other scientists from all sorts of scientific disciplines in the future.

With the growing needs for students to draw knowledge from multiple scientific disciplines, this integrated biology and chemistry course is relevant in adapting to these needs. Providing the future biologists with interdisciplinary training during their undergraduate science education allows them to become effective scientists who can integrate biology to other fields of sciences such as chemistry.

7. Recommendations

To further improve the iBC course of the ISLL, the following recommendations were made for future work:

- Reassess the sequencing of topics in biology and chemistry to fully maximize the integration of the concepts. This may involve discussing the matter among the faculty teaching both disciplines, the preceptors, and the teaching assistants;
- Conduct assessment on students' higher order thinking and measure their scope of understanding of the concepts. This is important as it will provide the faculty and other members of the teaching team evidence that what they are doing and the activities that they have prepared were effective in achieving the course's purpose;
- Realign the lecture and the laboratory activities. At present, the iBC has done so much about realigning biology concepts with chemistry concepts to ensure integration. However, it is also important to make sure that the topics and concepts discussed in the lecture are parallel to what are investigated by the students during the laboratories both in biology and chemistry; and
- Evaluate the nature and load of work given to the students taking the course. One of the things the project found out is that over the years of the implementation, there were semesters where a decline in the number of students taking the course is observed. One factor that contributed to this decline is the load of work given to students. The faculty and preceptors might want to find ways to adjust the load of work without compromising what the course intends to achieve.

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