ARTICLES

Using History and Philosophy as the Capstone to a Biology Major

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Abstract: Capstone experiences have high educational impact with a number of approaches for biology. In most capstones, students produce a major project, typically as an undergraduate research experience, with a primary goal to integrate students' learning. At Augustana, our senior biology capstone uses history and philosophy to frame students' reflections and to integrate their biological education within our liberal arts and sciences curriculum. In a flipped classroom approach, students write a response to the assigned reading before class, when the paper is discussed through student-led seminars. Assigned papers consider the philosophy and historical development of biology focusing on its three conceptual pillars: function, development, and evolution, allowing students to examine how biologists arrived at their current understanding of life. Assessment of ten years of course offerings indicates students' ability to write and speak are being successfully developed, but that thinking shows no significant learning gains between the midterm and final exams. Student quantitative and qualitative ratings of the course indicate that it is a valuable learning experience, despite its heavy workload and difficult nature.

Keywords: high impact educational practice, senior year, writing, speaking, critical thinking, functional biology, developmental biology, evolutionary biology, student learning outcomes

INTRODUCTION

High impact educational practices are teaching strategies in which "students invest time and energy over an extended period that has unusually positive effects on student engagement in educationally purposeful behaviour" (Brownell and Swaner, 2010). Capstone experiences are considered to be a high impact educational practice because of their ability to engage students and integrate their learning (Hauhart and Grahe, 2015). Rather than disconnected individual educational experiences (courses) a capstone experience should enable students to understand the connections between the courses and leave the program with an integrated, robust knowledge structure of their discipline and integrate that discipline into a broader understanding of the world - it is not just about biology, it is about embedding biology into the lived experiences of people (Smith, 1998). Research has shown that attending to students' engagement enhances their learning outcomes (Carini et al., 2006). Capstone courses engage students typically through projects, senior theses, or an undergraduate research experience (Hauhart and Grahe, 2015). What makes these engaging is students' sense of ownership and enfranchisement with their own learning - it becomes something they control in their own learning. Capstone courses can also provide an educationally purposeful activity by providing students with a forum to integrate their major and their entire undergraduate education (Kinzie, 2013). Typically, students go through the undergraduate curriculum ticking off their course requirements from a checklist without understanding the integration implicit in their general education requirements and how they relate to their major (Smith, 1998). By linking students' learning to their prior educational experiences, students are able to construct a more robust knowledge structure. In addition, facilitating the integration of students' learning with their own lived experience will increase their educational engagement by linking their personal to their academic lives making their learning relevant and significant. Capstone courses are one way to weave the different threads of students' undergraduate education and life into a coherent tapestry of learning and experience (Kuh, 2008).

A number of approaches exist for developing capstone courses (Davis, 2011). Some provide students with a service learning experience (Kerrigan and Carpenter, 2013). Others give students an undergraduate research experience (Wenk and Rueschmann, 2013). Still, others are designed to integrate the entire undergraduate program or simply integrate the different parts of students' major (Usher et al., 2010; Griffin and Burns-Ardolino, 2013; Redman, 2013; Stubbs et al., 2013). Many are part of the general (core) curriculum of the institution but most are housed within students' major (Kinzie, 2013). In addition, most capstone courses seem to be focused on skill development rather than on content mastery (Obringer and Kent, 1998; Haave, 2015b; Aguanno et al., 2015).

In the early 1990s, the Augustana Faculty of the University of Alberta revised their educational

curriculum making it a requirement that all majors either complete an undergraduate research experience or complete a course that enables students to critically reflect on their discipline's theoretical and historical development. Due to a lack of lab facilities, our biology major chose to develop and implement a course on the history and philosophy of biology. This task fell to me. During my 1996 sabbatical, I researched and developed History and Theory of Biology, a senior capstone course for the Augustana biology major. The course's learning goals were the development of students' writing, speaking, and thinking skills tied to a critical reflection of the historical development of our current understanding of life processes with an emphasis on evolution, genetics, and development (Haave, 2012). In this paper, I reflect on the efficacy of the course over the 10-year period 1998-2009 using students' marks and evaluations as the evidence for my analysis.

METHODS

Course description

The course under consideration is a senior (fourth-year) capstone course for the biology major of the Augustana Faculty at the University of Alberta: AUBIO 411 - History and Theory of Biology. The course content focuses on the historical development of evolutionary, developmental, and functional biology as the three primary conceptual foundations of biology (Haave, 2012). The goals of the course are to actively engage students in their reflection on Biology as a discipline by having students consider how and why biology is currently investigated. These goals lead to questions such as: What are the assumptions inherent in our approaches to biological investigation? Why am I training to be a biologist? How does my biological education inform me as a person and/or citizen? How will my biology education affect me to action?

Embedded in the course are the development of students' thinking and communication skills via a writing dossier in which students reflect and respond to the assigned course readings. In addition, students' speaking and research skills are developed through the requirement to lead two class seminars for which seminar leaders need to do some additional research on the paper assigned for that particular day. Thus, students are held responsible for the assigned readings by engaging them prior to class through a writing dossier and in-class through seminars in a manner consistent with active learning and flipping the classroom (Linton et al., 2014; Abeysekera and Dawson, 2015).

The period of assessment is the first year the course was offered (1998) until the year before my teaching duties were decreased due to an increase in my administrative load (2009). All students must complete this course to graduate with a major in biology from the Augustana Faculty. The student composition was typically students in their senior year but did contain a few junior students or those who returned for a fifth year. The pre-requisites for entry into the course were senior standing, and completion of six credits of freshman biology, six credits of sophomore genetics and biodiversity, and six credits of junior biology. Junior developmental biology was strongly recommended.

The course content was divided into four parts: I - an introduction to the philosophy of science; II - an introduction to the problems of doing history; III - the conceptual development of biology with a focus on evolution, development, and genetics; IV – the social aspects of modern biology. The course was structured around the discussion of assigned readings from the philosophy and history of biology with students required to read approximately two papers per week.

In the style of the flipped classroom, students completed a two-page typewritten response to the reading for entry to each class in which the paper was discussed. These responses comprise their writing dossier of which a small sample (approximately five) was marked. In addition, students provided at midterm and end of term, an analysis of their own writing that addressed their writing structure and style. This self-critique was assessed.

Each student led a seminar twice per term. These student-led seminars were evaluated by the instructor and students. Instructor and student comments (made anonymous) were returned to students at midterm as formative feedback. As formative feedback, the student-led seminars were weighted 1:2 for pre- and post-midterm evaluations. Writing dossiers were similarly weighted.

Students also evaluated their peers' contribution to the class discussion which informed the instructor's evaluation of student participation. This peer evaluation of participation was critical to ensure that all contribute to a robust intellectual conversation to facilitate student learning and discourage social loafing (Seidel and Tanner, 2013).

Students' understanding of the conceptual development of biology was evaluated with a midterm and final exam which were comprised of three short essays (one to three paragraphs each) at midterm, and four to five short essays on the final exam. Students had a choice of questions to answer, within constraints, to ensure that each part of the course was addressed. In addition, on both the midterm and final exams there was one common question which all students answered to evaluate students' ability to integrate their learning in the course; they considered how biological concepts developed over time and were influenced by both intellectual and social factors. It is this final question that I used to assess students thinking in the following analysis.

Assessment of achieving course learning goals

The efficacy of the course was assessed by

Table 1. Questions soliciting comments from students on the Universal Student Ratings of Instruction (USRI) form

Pre-2005*	Post-2005
• What aspects of the instructor's teaching did you find most valuable?	• What aspects of the course and/or instructor did you find most valuable?
• What aspects of the instructor's teaching did you find least valuable? What suggestions do you have for improvement?	• What aspects of the course and/or instructor did you find least valuable?
• Any additional comments that you would like to make.	• Please add any other comments that you would like to make about the course and/or instructor.

*In 2005 Augustana University College became a Faculty of the University of Alberta. This was accompanied by a change in the wording of some of the USRI questions

comparing midterm and end of term student results for their seminars (speaking skills), dossiers (writing skills), and integrative exam question (thinking skills). Student marks were analyzed using Students' paired t-tests to assess whether students' abilities improved between midterm and end of term. When the data did not pass a normality test, the Wilcoxon Signed Rank Test was used to determine statistical differences.

Students' assessment of their learning experience

Students' perception of their learning and the learning environment of the course were assessed by analyzing the end of term student evaluations considering both the Likert scale rating and student comments. Questions informing the analysis of students' perceptions of their learning and the course learning environment included: 1. workload, 2. difficulty, 3. clarity of the objectives, 4. achieving the objectives or increasing their knowledge, and 5. the quality of the learning experience. In 2005 Augustana University College became a Faculty of the University of Alberta. With this merger, some questions changed. For example, before 2005 the question asked whether students thought that the course was a positive learning experience whereas after 2005 students were asked whether the course was a very good learning experience. These two questions were analyzed separately due to differences in responses among the year cohorts.

Students' ratings of the course using a five-point Likert scale (1-5: strongly disagree, disagree, neutral, agree, and strongly agree) were first analyzed for significant differences among the year cohorts using the Kruskal-Wallis one-way ANOVA. When differences did not exist between the years, the 10 years of student evaluations were combined into one cohort and analyzed using Chi-square. Anonymous student comments written in response to three open-ended questions (Table 1) on the end of term course ratings (Universal Student Ratings of Instruction or USRI) were analyzed for common threads of perception towards students' own learning and their response to the character of the course as a learning environment. The total number of students completing the end of term evaluations over the ten-year span under study was 123-127 for each question: not all students responded to all questions.

RESULTS

The course offerings over the 10-year period consisted of relatively similar students with regard to student learning outcomes: The Kruskal-Wallis one-way ANOVA did not detect significant differences ($p > 0.05$) among the annual cohorts of students. Thus the student learning outcomes were treated as a single group (Chaplin and Hartung, 2012). Students' speaking and writing ability improved when comparing their pre and post-midterm seminar marks (Figure 1, Wilcoxon Signed Rank Test, $p \leq 0.001$) and writing dossiers (Figure 2, paired t-test, $p \leq 0.001$). However, student thinking as assessed by an integrative exam question did not change (Figure 3).

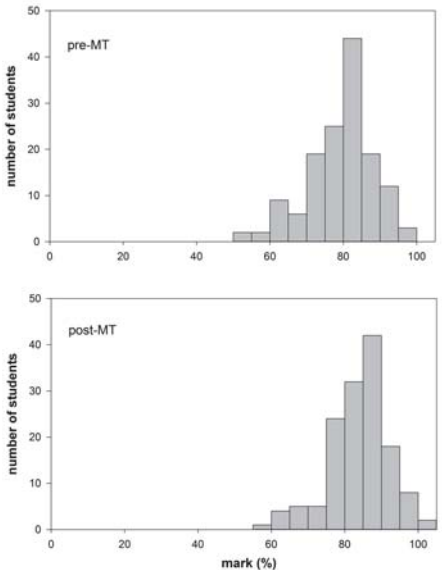

Fig. 1. Pre-midterm and post-midterm seminar percent mark distribution of combined student cohorts from 1998 to 2009. One-way analysis of variance did not detect significant differences among the individual year cohorts ($p > 0.05$). The decade of combined student marks was significantly different between the pre-midterm and post-midterm seminar mark (Wilcoxon Signed Rank Test, $p \leq 0.001$

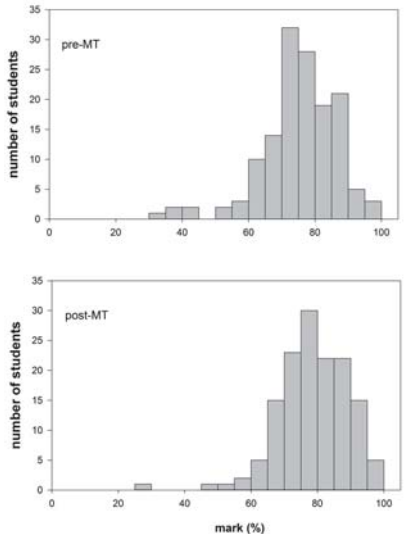

Fig. 2. Pre-midterm and post-midterm writing dossier percent mark distribution of combined student cohorts from 1998 to 2009. One-way analysis of variance did not detect significant differences among the individual year cohorts ($p > 0.05$). The decade of combined student marks was significantly different between the pre-midterm and post-midterm seminar mark (paired t-test, $p \leq 0.001$).

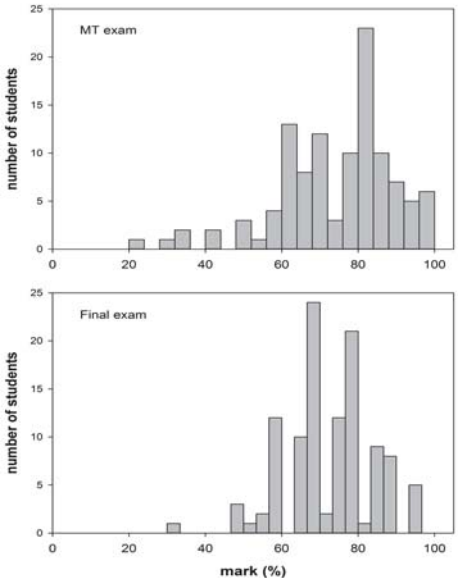

Fig. 3. Percent mark distribution for a midterm and final exam integrative question of combined student cohorts from 2000 to 2009. One-way analysis of variance did not detect significant differences among the individual year cohorts ($p > 0.05$). The decade of combined student marks was not significantly different between marks for the midterm (MT) and final exam question (two-tailed paired t-test $p > 0.05$).

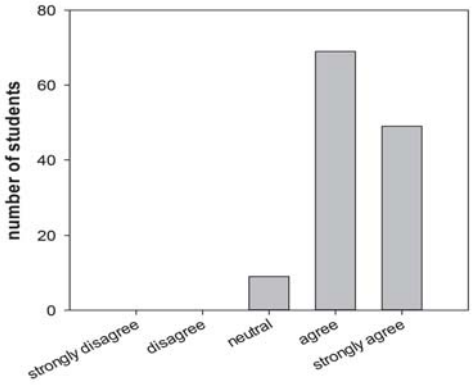

Fig. 4. Number of students (1998-2009) indicating that the course objectives were clear. Kruskal-Wallis one-way ANOVA did not detect significant differences among the year cohorts ($p > 0.05$). Chi-square analysis of all students (1998-2009) detected a significant difference ($p < 0.005$) among the choices of the entire 10-year cohort**.**

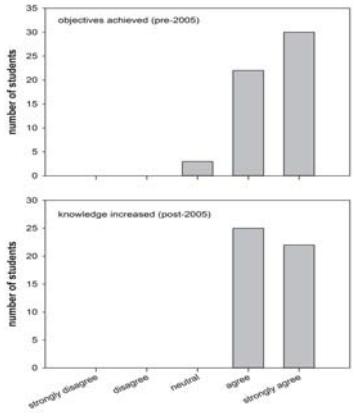

Fig. 5. Number of students reporting that either the course objectives were achieved (pre-2005) or that their knowledge of the subject matter increased (post-2005). Kruskal-Wallis one-way ANOVA did not find significant differences among the different year cohorts ($p > 0.05$). Chi-square analysis found significant differences ($p < 0.005$) among the choices when analyzed as two single cohorts pre-2005 and post-2005.

Kruskal-Wallis one-way ANOVA on ranks did not detect any significant differences ($P > 0.05$) among the year cohorts of students' rating for four of five course parameters. When analyzed as a combined single group Chi-square analysis detected significant differences ($P < 0.005$) with 86-100% of students agreeing that the objectives were clear (Figure 4), the objectives were achieved, that students increased their knowledge (Figure 5), and that the course is more difficult (Figure 6) and has a greater workload (Figure 7) than other courses. The Kruskal-Wallis one-way ANOVA on ranks did detect differences among the student cohorts rating the course as a learning experience (Figure 8). To tease this apart the cohorts were split into two analyzable groups based on the wording of the question which changed as a result of Augustana becoming a Faculty of the

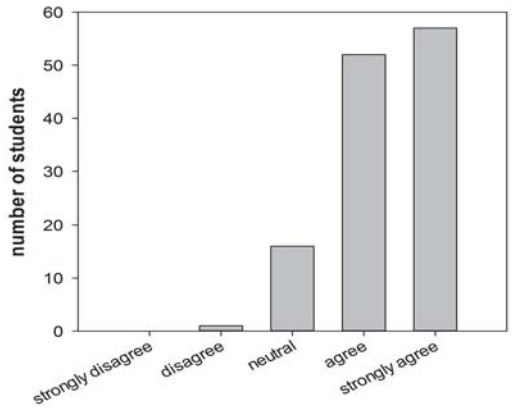

Fig. 6. Number of students (1998-2009) indicating that the difficulty of the course is greater than others they have taken. Kruskal-Wallis one-way ANOVA test did not detect significant differences among the different year cohorts ($p > 0.05$). Chi-square detected significant differences ($p < 0.005$) among the responses of the entire 10-year cohort.

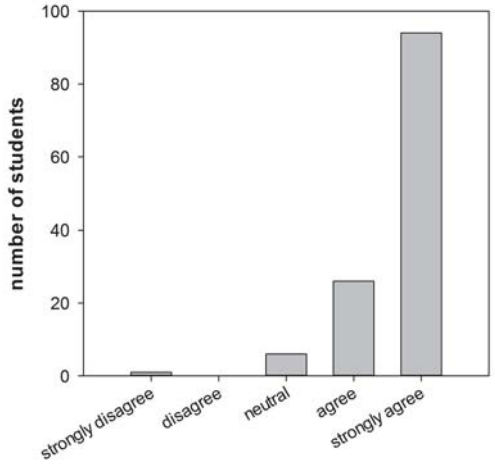

Fig. 7. Number of students (1998-2009) agreeing that the course had a greater workload than others they had completed. Kruskal-Wallis one-way ANOVA test did not detect differences among year cohorts ($p > 0.05$). Chi-square detected significant differences ($p < 0.005$) among the responses of the entire 10-year cohort.

University of Alberta in 2005. Dunn's Multiple Comparison test found that the 2007 and 2008 cohorts had significantly ($p < 0.05$) more students than other year cohorts disagreeing with the statement that the course was a very positive learning experience. However, most students still thought that the course was a positive learning experience.

The student written comments support their ordinal results. Student comments indicate that the course was very difficult with a high workload but that it was valuable and eye-opening (mind-opening in the words of one student). The student comments and ordinal data are somewhat contradictory; on the one hand, students complained about the workload and difficulty with some students commenting that the two-page response per reading, typically twice a week, was difficult. On the other hand, some students commented that preparing for class by writing a two-page response to the assigned reading was necessary to participate in the ensuing class discussions. Following are some sample student-written comments from the USRIs that indicate the tension between the value of the course and its difficulty and workload:

- But it's a good workload since all students are well prepared for exams.
- Reading & summaries are a LOT of work, but are necessary to understand the objective of the course.
- The Reading and Summaries [were valuable]. Though time consuming they forced me to read and get the work done.
- Summaries kept me on top of my work which makes studying easier.
- Though I cursed having to write summaries, often enough, I think it is the only method to ensure that people have read the article and understood. And this is vital if discussion is to take place.
- The summary each class makes sense but at times it got overwhelming.
- I did not enjoy writing a review for every class but it was needed in order to understand topics.
- Some of the readings were such a chore! I realize their importance and value. I'm just complaining.
- This course had a huge workload but I can see the value in it.
- Overall very interesting course, except for the grueling workload.

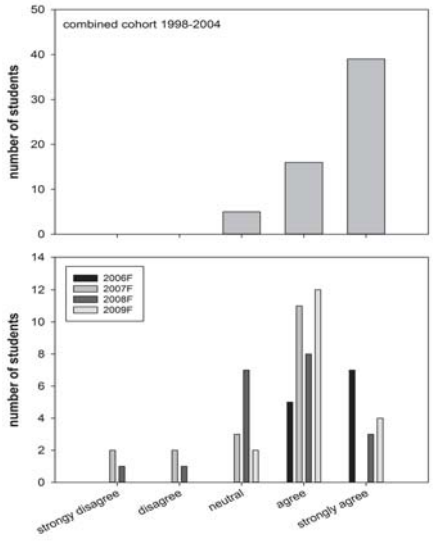

Fig. 8. Number of students rating the course as a positive learning experience. Kruskal-Wallis one-way ANOVA on ranks followed by Dunn's Multiple Comparison found the 2007 and 2008 cohorts to be significantly different ($p < 0.05$) among all student cohorts 1998-2009. There were no differences among the cohorts from 1998-2004. Chi-square analysis of the combined 1998-2004 group indicated that significantly more students agreed that it was a positive learning experience ($p < 0.005$).

DISCUSSION

The data indicate that students enrolled in Augustana's biology capstone course improved their speaking and writing skills but did not improve their ability to answer an integrative thinking question. Students indicated that the course met its stated objectives (pre-2005 question) and that their knowledge increased (post-2005 question) and that it was a good learning experience. However, the workload and difficulty of the course are high. A minority of students in the 2007 and 2008 cohorts disagreed that the course was a positive learning experience.

The results from the integrative exam question are clearly disappointing: I was expecting an increase in students' ability to integrate their learning and thus demonstrate improved thinking ability. Students typically perform poorer on the final relative to the midterm exam in the courses I teach (Haave, 2016) which may be due to the greater amount of material examined on a comprehensive final exam. However, students did not decrease their ability to answer an integrative thinking question as might be expected from trends in midterm versus final exam marks for my courses. On the other hand, the difficulty of assessing students' thinking ability has been identified (Bok, 2006) but can be approached using student self-reports (Tsui, 1999); students' comments and ratings of the course indicate their sense that their understanding and knowledge increased. The significant improvement in speaking ability appears to be mostly due to an increase in the mark of the bottom 25% of the students which is similar to results from other high impact practices (Brownell and Swaner, 2010) such as undergraduate research (Haave and Audet, 2013). Part of this effect may be due to the upper ceiling of possible marks.

My previous study found that most institutions require a capstone course of their biology majors but no other institution, except Augustana, uses history and philosophy to integrate students' biology program in their senior year (Haave, 2015b). Most biology capstone courses are structured around an undergraduate research experience. In contrast, a recent study reported that few capstone experiences in biochemistry and molecular biology are courses (Aguanno et al., 2015). Some have reported using history and philosophy to aid the doing of science by reframing the questions asked by biologists (Daggett, 2012; Kendig et al., 2012), as is done in the Augustana capstone. However, our course is the only one that uses history and philosophy to capstone a biology major but is not unique in its emphasis on developing students' communication and thinking skills in a seminar format, which integrates their learning from previous courses (Chaplin and Hartung, 2012). Students' self-assessments indicate that this approach is successful in engaging their reflection on biology as a discipline. Student comments and ratings indicate that the capstone course has a high impact on their learning as would be expected from a high impact practice (Kuh, 2008).

Although students identified the course workload and difficulty to be high as a result of the assigned readings and written responses, they understood their necessity for being able to engage in the intellectual class discussions. Something that I have learned over my many years teaching this course is that providing guiding questions, and better summarizing the discussion and reading before the end of class lessens the anxiety students have over peer-learning. Essentially, instructor-led closure at the end of each student-led discussion is necessary. I do not think that students' complaints about workload and difficulty are about the writing per se, but rather are indicating the effort required to think through the assigned readings with the writing being an exercise in thinking (Haave, 2015a).

Most capstone courses are disciplinary in nature with students writing comprehensive exams, papers, or engaging in field research (Kinzie, 2013). Field experiences seem to have the greatest impact on learning outcomes. Kinzie (2013) suggests that reflection goes hand-in-hand with integration and that instructors need to be purposeful in guiding students through the reflective process in order for students to integrate their educational experiences. The Augustana biology capstone course does this by providing students with a reading guide containing guiding questions. One conclusion (Kinzie, 2013) is that the ability to integrate needs to be scaffolded into degree programs. Expecting it in the final year, without proper preparation, is not the best way to achieve integration. I have been attempting to address this with the introduction of e-portfolios in my sophomore molecular cell biology course (Haave, 2016).

Similar to what has been reported for other capstone courses (Humphrey Brown and Benson, 2005), the Augustana biology major capstone is time-consuming to teach. Unlike other reported capstone courses, the Augustana biology capstone is not an undergraduate research experience. Rather, it is comprehensive in nature providing students with the opportunity to reflect on the discipline and integrate their previous learning experiences. Students find our capstone to be significantly different from other courses, and recognize the difficulty in synthesizing previous learning.

Some biologists have reported concern (Carter et al., 1990) that traditional approaches to teaching (lecture and content) are insufficient to teach students to think critically, problem solve, and to collaboratively work as a team; a concern shared by Augustana biologists. Thus, I designed our biology capstone course to have students think critically and work collaboratively through writing, seminar presentations, and discussions understanding that

biological problem solving would be considered and developed prior to this course in our curriculum (e.g. specifically our sophomore molecular cell biology course, but also in other junior courses centered around the completion of a research project).

A faculty survey (Carter et al., 1990) found that few faculty were concerned with providing a summary course, research experience, a consideration of the history and philosophy of biology, or ethical questions in biology. In contrast, surveyed students indicated a desire that their biology program considers values and ethics (Carter et al., 1990). The Augustana capstone does this when considering why falsifying data is treated much more harshly by the research community than plagiarizing. The course also considers the values inherent in the questions we ask as biologists and how we frame our interpretation of the results; namely determinism vs indeterminism, destiny vs free will, genetics vs environment and experience. Our biology capstone examines how our worldview can impact how we frame our questions and interpret our data. Augustana biology students considering graduate school are encouraged to enrol in our senior courses offering an undergraduate research experience.

Some of the questions that have been raised (Carter et al., 1990) are addressed by our capstone course at Augustana. Using the history and philosophy of biology as the focal point for the course makes it accessible for students interested in a variety of biological sub-disciplines. This approach enables the integration of the different sub-disciplines of biology to which students would have been introduced in their prior years of study and also enables a review of biology in a new context without simply re-teaching introductory biology. Integrating people, history, and context into biology capstone courses can make biology relevant to students (Chamany et al., 2008) and is the approach taken by Augustana's capstone course which considers the history and role of individuals in the development of modern biology. The history of biology is rich and thus needs to be limited in scope to be addressed in a single capstone course. The Augustana capstone uses the thread of the historical relationship between evolution, development, and inheritance as its content filter using key texts (see a sample reading list in the 2009 course syllabus: http://aug.ualberta.ca/B411F2009) which do a good job of integrating these topics.

One of the advantages of including a consideration of the philosophy of biology as it developed over the last couple of centuries is that it addresses different modes of inquiry such as the reductive and holistic approaches of molecular and field biology. To limit the scope of our capstone course, I chose not to include a study of current biological literature, instead focusing on secondary sources which consider biology's philosophy and history. Our program, however, is designed such that students must take a senior course in biology which does consider current biological research. However, there is not one particular course that does this: students have the opportunity to choose a senior course in biology that is within their area of interest (e.g. microbiology, biochemistry, developmental biology, conservation biology). Thus, our capstone course provides an opportunity for students to consider the theoretical assumptions of modern biology and to understand the historical constraints that have influenced current biological concepts and experimental approaches. But our capstone course does not further develop students' biological research skills. That is developed by a second senior course requirement in our degree program. The Augustana biology capstone course integrates their prior knowledge into a coherent structure but does not attend to all skills necessary for students to become adept biological researchers: a single capstone course cannot accomplish all of the goals of a biology major, choices must be made.

It has been suggested (Carter et al., 1990) that biology curricula need to better address the interdisciplinary nature of the world's present problems and not teach biology in a vacuum or be isolationist in its approach to educating students. Rather, there needs to be an acknowledgement of the courses being taken outside of the major and attempts made to integrate biology teaching with teaching in the humanities and social sciences. The Augustana biology capstone takes this suggestion to heart with its focus on the history and philosophy of biology.

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