REVIEW OF THE UNIVERSITY OF DELAWARE'S DEPARTMENT OF BIOLOGICAL SCIENCES CURRICULUM GOALS AGAINST NATIONAL EXPECTATIONS

by

Benjamin G. Rohe

An education leadership portfolio submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Education in Educational Leadership

Fall 2018

REVIEW OF THE UNIVERSITY OF DELAWARE'S

DEPARTMENT OF BIOLOGICAL SCIENCES CURRICULUM GOALS

AGAINST NATIONAL EXPECTATIONS

by

Benjamin G. Rohe

Approved: ____
Chrystalla Mouza, Ed.D.
Director of the School of Education

Approved: ____
Carol Vukelich, Ph.D.
Dean of the College of Education and Human Development

Approved: ____
Douglas J. Doren, Ph.D.
Interim Vice Provost for Graduate and Professional Education

I certify that I have read this education leadership portfolio and that in my opinion it meets the academic and professional standards required by the University as an education leadership portfolio for the degree of Doctor of Education.

Signed: ____

Zoubeida Dagher, Ph.D.
Professor in charge of education leadership portfolio

I certify that I have read this education leadership portfolio and that in my opinion it meets the academic and professional standards required by the University as an education leadership portfolio for the degree of Doctor of Education.

Signed: ____

Danielle Ford, Ph.D.
Member of education leadership portfolio

I certify that I have read this education leadership portfolio and that in my opinion it meets the academic and professional standards required by the University as an education leadership portfolio for the degree of Doctor of Education.

Signed: ____

Chrystalla Mouza, Ed.D.
Member of education leadership portfolio

I certify that I have read this education leadership portfolio and that in my opinion it meets the academic and professional standards required by the University as an education leadership portfolio for the degree of Doctor of Education.

Signed: ____

Carlton Cooper, Ph.D.
Member of education leadership portfolio

ACKNOWLEDGEMENTS

I am ever grateful to my advisor and committee that helped me along my way through this program and education leadership portfolio (ELP). Dr. Dagher for her constant input on the process and writing. By now she must have read so many versions of this document that they all run together and cause migraines. I am thankful for Dr. Ford for being a voice of reason when I proposed an amount of work that would satisfy several ELPS and for being a resource for Science Education information. I am thankful for Dr. Mouza, for being a committee member and instructing a terrific course on Curriculum Planning and Design, which ended up being a major focus of my ELP. And also, I am thankful for Dr. Cooper who has been involved in one-way or another with every opportunity I have had to teach, mentoring me the whole way.

I would also like to thank my wife Shawn and daughters Hannah and Natalie. Getting any graduate degree is an effort that involves everyone in the family. Shawn and the girls have spent many nights getting through the nighttime process without me for the past 6 years as I attended countless night courses, taught evening classes and TA'd late lab sections, stayed up late to write reports, submit work online, and complete this portfolio and reflection paper. You are so very appreciated and loved. I could not have done it without your efforts.

And finally a great deal of gratitude goes to friends, family and colleagues that have helped in so many different ways from leading independent study, offering input, participating in interviews, scheduling my classes as a student, making sure I always had a class to teach, and generally offering support and camaraderie. I now know this is not about me but everyone involved. Thank you.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The University of Delaware Department of Biological Sciences is in a period of change. Pressures, both internally and externally, are driving towards a greater teaching demand. The University of Delaware itself is under a leadership directive that has all departments focusing on performance goals along the lines of peer institutions from the Association of American Colleges and Universities (AACU) and the corresponding field's national expectations. Since the Department of Biological Sciences has not undergone an internal or external review in more than five years, it seemed timely to find out how its programs align with national recommendations and best practices in biology education.

Several sources were utilized to explore the department's core program. Alignment of program goals with the national recommendations was determined through content analysis of the American Association for the *Vision and Change in Undergraduate Biology Education: A Call for Action* (AAAS, 2011). Private documents from the Department of Biological Sciences such as the last two Academic Program Reviews, Strategic Plan, and Curricular Mapping initiatives were also analyzed for evidence of alignment with the AAAS recommendations. Alignment with the University of Delaware's General Education outcome goals was examined using the Department of Biological Sciences public websites including Course Offerings, Degree Requirements, Chair's Welcome, and Undergraduate Program pages. Finally, several faculty in the department who teach the required courses for the B.S and B.A. biology majors were interviewed for their perceptions on the department, curriculum change, alignment with national recommendations and suggestions for improvement.

After examining the research literature, analyzing an extensive set of documents, and interviewing a sample of faculty, I developed a set of recommendations pertaining to three improvement goals. Improving the outcomes for goal one include aligning their public profile and curriculum with peer and aspirational institutions as well as the national recommendations from AAAS. Recommendations for this goal include 1) creating a new strategic plan, public profile, and Chair's Welcome emphasizing career paths, 2) increasing the focus on Ecology and Evolution content as well as utilization of models and simulation skill set, and 3) restructuring the Biotechnology degree to include more bioinformatics or computational biology. Improving the outcomes for goal two should include better alignment with the University of Delaware General Education goals. Recommendations for goal two include 1) having course instructors consider including creative ideation and ethical implications, 2) certifying courses that satisfy General Education requirements, and 3) advertising such courses as options for non-majors or as efficient option for life science majors. The third goal includes increasing the quality of scientific content and skills development in the planned and taught curriculum. Recommendations for this goal are 1) beginning a new culture of advancing instructional development, 2) reconsidering promotion and tenure requirements to include instructional performance or development, 3) creating courses focusing on developmental biology, and 4) to consider following instructional models coming from integrated Biology and Chemistry for all introductory courses.

Chapter 1

INTRODUCTION

In the world of higher education it is important for programs, departments and colleges to reflect on their practices with a critical eye to determine if they are working efficiently and effectively to create a quality informed and skilled graduate. The goals that are set to develop a learned and skilled graduate are informed by entities inside and outside an institution. From within, a university develops the general education goals that identify the set of dispositions and skills that students are expected to develop by the time they graduate from the university. The department being a smaller unit therein often reflects the general educational goals in its own mission statements, strategies and student outcome goals. However, a department being more tightly focused on disciplinary knowledge and practices has other entities outside the institution to which it is accountable, the national funding and regulatory foundations. These foundations and agencies keep a sharp eye on the current trends and directions of the field of study. The department then has to develop students who are knowledgeable and competent in their chosen field of study or subsequent graduate undertaking.

The University of Delaware Department of Biological Sciences is expected to respond to goals set by the University of Delaware and the foundations and agencies that fund and monitor the advancement of the life sciences. To that end this project was designed to determine how the Department of Biological Sciences has aligned its curriculum goals with those of the goals of University of Delaware's General Education and the national recommendations for biology education from the American Association for the Advancement of Science's (AAAS, 2011) *Vision and Change* document.

Relative to this document, curricular change was planned based on the department's 2012 Academic Program Review (APR) (University of Delaware Department of Biological Sciences, 2012). That review was an internal one, while the one performed in 2006 was external with faculty and experts from other institutions comparing the Department of Biological Science's program to their own and national standards for accreditation (University of Delaware Department of Biological Sciences, 2016). In the time that these reviews have been undertaken, curriculum and pedagogy have advanced. Most educational research documents are referring to developing 21st century skills, when defining the educator, the technology and pedagogy for future instruction. It is a different landscape in education than when the last APR was performed with external reviewers.

The purpose of this project is to provide recommendations for improving the alignment of the department's programs with institutional and national goals. The research necessary for developing these recommendations consists of reviewing program requirements of the University of Delaware Department of Biological Sciences as compared to peer and aspirational institutions as well as national recommendations for degrees offered, core required courses, content and curriculum implementation. To inform these recommendations, I conducted a literature review of the history of biology education in higher education, determined program requirements at peer and aspirational institutions and programs, and reviewed core coursework in programs in those institutions to determine the core required coursework for life science majors. In addition, I analyzed the *Vision and Change* document and performed multiple alignments of goals and outcomes to determine the department's purposeful and inherent alignment with those internal and external goals. Finally, I interviewed a sample of faculty to determine how they perceive the connections between department goals and those of the national recommendations.

This education leadership portfolio contains seven artifacts that document the steps followed to review the University of Delaware Department of Biological Science's curricula, plan and execution of conferring content knowledge and skills onto undergraduate students in the life sciences relative to national recommendations. Some artifacts, namely Artifacts 2 and 3 were completed while Artifact 4 was begun prior to developing the project proposal. The three artifacts include an analysis of the *Vision and Change* document, analysis of relevant programs at peer and aspirational institutions, and curriculum review and comparison to those institutions. Artifacts 5, 6, 7 and 8 were planned to support the process of developing recommendations for this study. A description of each artifact is provided below.

1. ELP Proposal. The ELP Proposal Document is a narrative description of the work I planned to complete through the ELP II and ELP III portion of the Educational Leadership Doctorate program. This proposal articulates the focus of the study and describes the organizational context and my role in the University of Delaware Department of Biological Sciences. This proposal reviews the current efforts of the department to utilize evidence based educational research to keep the curriculum and methods of instruction up to date with peer and aspirational institutions and attempt to improve student-learning outcomes. The ELP Proposal identifies the steps that will be taken to complete this study. Some of the artifacts that were included in the original proposal were modified as more data or resources became available (see Appendix A).

2. Analysis of Peer and Aspirational Institutions. The purpose of this analysis was to serve as a means for comparing core program requirements of the University of Delaware Department of Biological Sciences to those of peer institutions, and also to identify core-required courses. These courses were then the focus of the subsequent analyses reported in Artifacts 5 Curriculum Mapping and 7 Faculty Perceptions. The areas for comparison included faculty and student population, degree offerings, degree requirements, mission statements and student outcomes.

This artifact includes coded and sorted publicly available website information from many University of Delaware peer and aspirational institutions such as University of Maryland College Park, University of Massachusetts, University of Richmond, Princeton University, Rutgers University, and Cornell University. Similar departments of biology or life sciences websites were researched for the list of courses that have been required, selective (chosen from a small group of courses to fulfill a required category) or strongly recommended electives. Further information gained from the websites included demographic data such as lists of majors, faculty size, and student body size as well as mission statements. The University of Delaware's mission statement and public information were acquired during the completion of this artifact, and were later analyzed to determine if the university aligned with the AAAS documents recommendations for content and skills for biology graduates.

In this document recommendations were made for adjusting the University of Delaware course requirements to align with peers. The Undergraduate Program Committee has already used this document in the discussion and resolution of changes to the course requirements. Initially, this document was used to identify peer institutions; it was used again in Artifact 7 Faculty Perceptions, to determine which faculty members were to be interviewed. Only faculty who taught courses determined by this artifact to be required biology curriculum classes were included in the sampling for interviews (See Appendix B).

3. Content analysis of the *Vision and Change* Document. The purpose of this study was to gain deeper knowledge of the evidence that supported the recommendations from AAAS for content and skills and determine if the recommendations are still supported or refuted by current published discipline based educational research (DBER). The AAAS *Vision and Change* (AAAS, 2011) document is a compendium on the desired state of biology education and served a role in the Department of Biological Sciences 2012 Academic Program Review as the national recommendations to meet in the categories of student learning outcomes for content and skills. In this document, the most revered funding bodies in science education laid out the issues in biology curriculum. It also contained the vision and mission for creating a curriculum that did the most benefit to an undergraduate student in the life sciences. However, it was not just an impressive policy document. It was grounded in evidence and strategies for successful student learning, pedagogy and assessment. This artifact is a comprehensive summary of all the strategies, rubrics, assessments and goals that informed the construction of the faculty interviews protocol completed in Artifact 7 Faculty Perceptions. The tangible result of this artifact was an outline for the interviews and survey (See Appendix C).

4. Strategic Goals Alignment. The purpose of this artifact was to determine if the University of Delaware's Department of Biological Sciences displayed or maintained a public appearance of alignment with the national recommendations from the AAAS. This artifact served as the second source of evidence on record for student learning goals and skills as determined by the Department. In this artifact, the mission statement and "Chair's Welcome" of the Department of Biological Sciences website was examined against the AAAS document. The results from that study showed there were some gaps in the department's mission statement that did not address the ability to use the recommended modeling and simulations. Because mission statements are idealized and often lack the particular strategies or plans as to how the goals shall be attained, this artifact also served to inform Artifact 7 Faculty Perceptions, in terms of developing the questions for the interview protocol (See Appendix D).
5. General Education Curriculum Mapping analysis. The purpose of this artifact was to determine how the curriculum goals of the University of Delaware Department of Biological Sciences mapped against the University of Delaware General Education Student Outcome Goals. During my tenure in the Educational Doctorate program the University of Delaware Department of Biological Science's faculty and administration met at a summer retreat (2016) and mapped the instructors' perceptions of how well their courses met the recommendations for the General Education goals from the University of Delaware. The goal of the retreat was to determine which courses could be certified as satisfying general education goals. For this artifact, the original curricular map was truncated to only

include the courses determined through Artifact 2 Analysis of Peer and Aspirational Institutions, to be Core Required classes. No analysis was provided from the Department of Biological Sciences, so the analysis performed in the discussion section of this artifact took into consideration how these courses scored against the recommended content and skills outcomes from *Vision and Change,* as a means to indirectly determine content and skills coverage by the department (Appendix E).

6. Comparison of General Education Recommendations at the University of Delaware to AAAS Recommendations. The purpose of this comparison was to determine how well the General Education objectives aligned with the AAAS recommendations. This allowed for some inference on how well the AAAS recommendations were covered by the curriculum goals as determined by the curriculum mapping in Artifact 5 General Education Curricular Mapping. This artifact also informed the discussion on the alignment with the department goals and strategies with both the general education and AAAS goals that occurred in Artifact 7 Faculty Perceptions. On the University of Delaware General Education website (sites.udel.edu/gened/) were 5 highlighted objectives expected of a University of Delaware graduate. These goals included the ability to read critically, communicate effectively, work collaboratively, critically evaluate, and reason quantitatively (University of Delaware, 2017a). Comparing the General Education goals to the AAAS documents goals again made clear the gaps between the status quo and the national standards at the university level. This artifact

helped guide the dialogue with faculty during subsequent interviews with faculty summarized in Artifact 7 Faculty Perceptions (See Appendix F).

7. Faculty Perception of University of Delaware Department of Biological Sciences Alignment and Delivery of Curriculum and Pedagogy. This artifact summarizes the University of Delaware Department of Biological Sciences faculty perceptions as to how well the content, skills, pedagogy and assessment recommended by the AAAS have been implemented in the department as stated in Artifact 4 Strategic Goals Alignment. Faculty members that were included in the interviews had been determined by Artifact 2 Analysis of Peer and Aspirational Institutions. That included faculty that had taught within the last 3 years, BISC207 & 208 Introductory Biology Courses, BISC305 Cell Biology, BISC401 Molecular Biology of the Cell and BISC403 Genetics. This course selection was based on the required lecture courses for both the B.A. and B.S. degrees in biology. The topics of discussion were determined by completion of all previous artifacts and an interview protocol was developed to guide the discussion. The interviews determined whether or not the faculty felt as though they have conveyed the content or transferred the skills to the students, explored their attitudes towards the current pedagogy and assessments as well as curricular reform. The interviews were recorded and transcribed, then coded for evidence or lack thereof as to the transfer of content and skills. Overall this artifact was intended to go beyond the analyses presented in Artifacts 2 Analysis of Peer and Aspirational Institutions, 4 Strategic Goals Alignment, 5 General Education Curriculum Mapping and 6 Comparison of General Education Recommendations at the University of

Delaware to AAAS Recommendations, which were focused on publicly available documents. This artifact constituted a miniature program evaluation. Most of the recommendations for improvement of instruction, pedagogy and assessment came from this artifact (See Appendix G).

8. Literature Review of Biology Pedagogy and Curriculum Trends. The purpose of this literature review was to survey research pertaining to biology education from historical perspectives and provides a local context for subsequent analysis. This literature synthesis was based in the history and reform of biology curriculum and pedagogy in higher education. It served as a reference for recommendations and methodologies that followed (See Appendix H).

In the following chapters, the above artifacts and published literature on discipline based educational research are used to support the recommendations.

Chapter 2

PROBLEM STATEMENT

The University of Delaware Department of Biological Sciences, as with other peer and aspirational university's biology or life science departments, is experiencing pressure from different sources. Firstly, in the current research-funding environment, many university faculty members are finding it difficult to get research funding and the undergraduate demand for careers in academia and industrial research is waning (Holm, Carter & Woodin, 2011). This leads to a transition from 75 percent or greater research workload to an increasing teaching workload for many research faculty, and the request of increasing course load for teaching faculty, often referred to as Continuing Non-Tenure Track or CNTT faculty.

Secondly, even though the number of undergraduates majoring in the biological sciences seems to be on the decline, the biology courses enrollment is as strong as ever. The growing student population in the College of Health Sciences is now driving the demand for more biology courses. As identified through the udel.edu/registrar course search webpage, the enrollment for BISC207 and BISC208 in 2018 reached 1058 students (University of Delaware, 2018a), while in 2016 there were only 639 students enrolled as biology majors and the trend was for declining biology majors as shown in Table 1.

Thirdly, a recent spate of transitions in the University from four presidents (including interims), two deans and four department chairs (incoming 5th chair predicted by Winter semester of 2019) has led to discontinuity in leadership. This is further compounded by what may be labeled as bulk faculty retirement and departure that has led to a turnover of the department's teaching faculty over the last ten years. From 2006 to 2014, 12 faculty that taught the undergraduate level have retired, or will in the next year (University of Delaware Department of Biological Sciences, 2014). In that time, the department has hired nine faculty members and was recently approved for three more. However, the teaching load has slowly increased over the first few years and while this slow start is beneficial to the incoming faculty, it does put a strain on the respectively smaller faculty population. This stress is compounded by the increase in the instructional workload resulting from the growing student body as shown in Table 1.

Table 1
Enrollments by Major from 2007 to 2016

	Majors							
	CHEM-BAAS	CHEM-BSAS	EXSC-BS	MDD-BS	MLS-BS	BIS-BAAS	BIS-BSAS	Total
2007 Fall Semester	37	76	165			899	26	1203
2007 Spring Semester	32	65	158			786	24	1065
2008 Fall Semester	47	81	208			866	20	1222
2008 Spring Semester	43	68	181			812	26	1130
2009 Fall Semester	52	86	452			872	17	1479
2009 Spring Semester	48	69	295			770	23	1205
2010 Fall Semester	46	79	534			757	26	1442
2010 Spring Semester	49	80	462			751	25	1367
2011 Fall Semester	36	83	566			753	21	1459
2011 Spring Semester	48	73	511			685	29	1346
2012 Fall Semester	34	106	645			726	13	1524
2012 Spring Semester	34	94	551			678	22	1379
2013 Fall Semester	50	127	631	3	70	696	18	1595
2013 Spring Semester	31	113	620	1	2	628	18	1413
2014 Fall Semester	39	135	679	8	78	685	16	1640
2014 Spring Semester	39	121	646	3	67	608	18	1502
2015 Fall Semester	28	161	656	27	69	649	19	1609
2015 Spring Semester	35	143	664	5	78	621	15	1561
2016 Fall Semester	31	143	610	71	71	687	55	1668
2016 Spring Semester	31	148	651	26	69	617	22	1564
Average student loss/gain per semester	-0.3	3.6	24.3	1.3	3.45	-14.1	-0.2	18.05

Source: University of Delaware Registrar's Office.

All these factors interfere with the implementation of the goals and strategic plan of the department molded over the same 10-year period in which the two previous APRs occurred. Thus the problem statement of this proposal is as such: How does the Department of Biological Sciences address national directives as expressed by the AAAS's *Vision and Change* document in its curriculum and assessment?

The document entitled *Vision and Change in Undergraduate Biology Education, A call to Action* (AAAS, 2011) is a summary of the findings and discussions from a national conference hosted by the American Association for the Advancement of Science (AAAS) in association with National Science Foundation (NSF), National Institutes of Health (NIH) and the Howard Hughes Medical Institute (Medina, Ortleib & Metoyer, 2014). The NSF, NIH, and HHMI are three of the major funding bodies in biology education as well as for national basic biology research. The journal, *Science*, published by the renowned AAAS, is one of the most well regarded journals in the field with the 12th highest impact factor of all biomedical journals. These national organizations have the power and influence to make changes in biology curricula at a national level. When they speak everyone listens.

The demands on current life science and biology departments listed above, as well as the stigma that most life science courses are taught in a classical lecture style with an emphasis on rote memorization, required a reconsideration of how the life sciences should be taught, the learning outcomes associated with them, and the key concepts any student undertaking the life sciences should understand thoroughly (Mulnix & Vandegrift, 2014). The *Vision and Change* document is over 60 pages long with five chapters and many thought-provoking concepts. The following excerpt from an editorial from the National Association of Biology Teachers President Mark D. Little (2013) captures cogently the few key student outcome goals and concepts:

> "…. for a student to be biologically literate, he or she needs to have an understanding of five core concepts. These are (1) Evolution, (2) Structure and Function, (3) Information Flow, (4) Pathways and Transformation of Energy, and (5) Systems. The report calls for these core concepts to be integrated with core competencies and disciplinary practices, including (1) the ability to apply the process of science, (2) the ability to use quantitative reasoning, (3) the ability to use modeling and simulation, (4) the ability to tap into the interdisciplinary nature of science, (5) the ability to communicate and collaborate with other disciplines, and (6) the ability to understand relationships between science and society."

The purpose of this ELP is to compare the University of Delaware's Department of Biological Sciences curricular goals and implementation to national recommendations for student learning and skills goals, as well as the alignment with the University of Delaware General Education goals and the finally the implementation of the curricula. It is with this in mind that I reviewed and analyzed the Department of Biological Sciences official documents such as APR's, mission statement, course descriptions, offerings and listing of required courses for several undergraduate programs as well as the University of Delaware General Education goals to determine the extent to which the department is meeting the goals described by the *Vision and Change* document. I also analyzed the extent to which these documents meet the University of Delaware's General Education goals. In an effort to validate that information, faculty interviews were conducted to determine if the Department of Biological Sciences is upholding the efforts outlined in the 2012 APR for student learning, skill transfer, pedagogy and assessment as perceived by faculty.

Chapter 3

IMPROVEMENT GOALS

The purpose of this study is to identify the extent of which the biology curriculum, both portrayed publicly by mission statements, program requirements and course offerings as well as how the program is perceived by faculty, matches the recommendations of the General Education student outcome goals as well as those from the AAAS' *Vision and Change* (Brewer & Smith, 2011) document through well informed guided faculty interviews and analysis of publicly and privately viewable documents. The purpose of this analysis is to identify strengths, weaknesses, opportunities and challenges as the basis for recommendations for the Departments Chair's and faculty to take towards aligning the department more with the national vision.

The department's leadership is open to receiving recommendations that are intended to support the goal of aligning its course requirements to the institutional (UD General Education) and national (Brewer & Smith, 2011) visions. The recommendations arising from this ELP could be shared with the incoming department chair, the Undergraduate Program Committee and other stakeholders. The ultimate goal of the resulting recommendations is to support the Department of Biological Sciences in

1. Creating a public profile and curriculum that aligns with peer and aspirational institutions and the national recommendations.
2. Improving alignment with the University of Delaware General Education goals.
3. Improving the quality of scientific content and skills development in the planned and taught curriculum.

In an effort to gather the evidence needed to create these recommendations a series of publicly and privately available documents were analyzed. Where relevant, information from peer and aspirational institutions was analyzed. The rest of this chapter summarizes and describes the methods used to arrive at the recommendations pertaining to each goal.

Goal 1: Creating a public profile and curriculum that aligns with peer and aspirational institutions and the national recommendations.

This goal was achieved by first collecting mission statements, strategic plans, examples of curriculum (program requirements) and institution demographics. The means for comparison were determined by searching for regional departments of equal size and scope to the University of Delaware Department of Biological Sciences (Appendix B, Table B.4), as well those institutions outlined in President Assanis' State of the University Address presentation (2016). These comparable departments were then searched for their mission statements, program offerings and course scheduling. The University of Delaware's Department of Biological Sciences program was compared against these institutions. The analysis identified the number and classification of the core-required courses. The list of six courses was then used to determine the inclusion/exclusion criteria for faculty interviews (Appendix G).

Course offerings then also served as a topic of discussion during the faculty interviews to determine if the curriculum had extraneous offerings or if any courses were absent from the core-required list. Program offerings (majors) were also a topic of discussion during the interviews and faculty insight was gained which informed the recommendations for program restructuring. The recommendations I had made based on alignment with peer and aspirational institutions were considered acceptable by the Undergraduate Program Committee. The recommendation for the mission statements at the University of Delaware Department of Biological Sciences included advertising the majors offered towards particular career paths as noted in Figure 1. I also recommended that any future advisement of students interested in medical school should be directed towards the B.A. course requirements, which was in the process of being restructured for the benefit of that student population.

Figure 1: List of recommendations and artifacts for evidence of goal 1 improvement.

Artifact Used in Analysis:	Recommendations:
• Artifact 2: Analysis of Peer and Aspirational Institutions • Artifact 3: Vision and Change Analysis • Artifact 4: Strategic Goals Alignment • Artifact 7: Faculty Perceptions	• Create new strategic plan, public profile and Chairs Welcome emphasizing career paths • Increase focus on Ecology and Evolution content as well as utilization of models and simulation skill set • Restructure the Biotechnology degree to include more bioinformatics or computational biology

Improving the outcomes for goal 1 should include aligning public profile and curriculum with peer and aspirational institutions as well as the national recommendations from AAAS. Evidence for the recommendations can be found in the listed artifacts.

It was also recommended that The University of Delaware's Department of Biological Sciences consider aligning itself with other peer institutions such as University of Maryland College Park, University of Pennsylvania, University of Massachusetts Amherst, University of Pittsburgh, SUNY Stonybrook or Cornell and the two aspirational institutions of University of California Davis and Princeton University in offering an B.A. or B.S. in Ecology & Evolution, the second most popular degree among the given peer and aspirational list behind Biology (Appendix B, Table B.4). This may be a long-term consideration as requisite coursework and instructional faculty that specializes in evolution would be needed, or research faculty with an interest in the field would need a reconfiguration of workload.

Also the creation of a bioinformatics or computational biology program was recommended to make the scope of program offerings more comparable to the peer and aspirational institutions as well. Bioinformatics, Computational Biology or Quantitative Biology is the third most frequent degree offering. When comparing to programs such as University of Maryland Baltimore County, University of Pennsylvania, University of North Carolina Chapel Hill, University of Pittsburgh, SUNY Stonybrook or Cornell University, the lack of such a program became apparent at the University of Delaware (Appendix B, Table B.4). Such a degree could be offered by the Department of Biological Sciences or co-offered with the Department of Computer and Information Sciences. Possibly as the program is building, biology could be a concentration in the computer science leading eventually to a Bio-Informatics B.A. or B.S. degree. There is a current Computer Science B.S. program in the computer science department, but the course catalog does not list any associated concentrations or specializations.

The other possible offerings denoted as deficiencies in the University of Delaware's Department of Biological Sciences major listing include Environmental Studies and Neurobiology (Appendix B, Table B.4). It is however, more difficult to recommend creating degrees in those majors as the University of Delaware already offers comparable degrees from the Department of Geography, Environmental Science and Environmental Studies Program and the Department of Psychological and Brain Sciences, respectively.

Of special interest to this study was the requirement of genetics as a core-required course. Upon the onset of this study, the department's Undergraduate Program Committee was considering a change to the required coursework for the B.A. of Biology degree. When compared to peer and aspirational institutions, Genetics was determined to be a required course (Appendix B). It was therefore this author's recommendation to the Undergraduate Programs Committee that genetics stay a required course in almost all majors related to biological sciences. The recommendation that the B.A. in Biological Sciences have the rigor increased was validated by emphasizing that the B.A. of Biology was a popular option for students moving on to medical, dental and veterinary graduate school. This was recommended to improve the students' readiness and success rate in those fields.

Also when considering preparing students for particular fields or career paths, the University of Delaware Department of Biological Sciences could benefit from better advertising the majors offered towards particular career paths. It was recommended that the programs offered by the Department of Biological Sciences have a description of the types of career that would benefit from each particular undergraduate program. This method of advertisement is being used by several of the fellow peer and aspirational institutions such as University of Pennsylvania, University of Pittsburgh, Princeton University, Swarthmore College, University of Maryland Baltimore County, University of Virginia, University of North Carolina Chapel Hill, and the University of Vermont (Appendix B, Addendum). Overall, the department does not offer strong evidence for which majors, minors or concentrations would benefit particular career paths.

Secondly, a transcript of the Chair's Welcome and departmental strategic plan webpages were analyzed for their alignment with the AAAS *Vision and Change* content and skills outcomes recommendations for graduates of life science programs. It was determined that the Department of Biological Sciences strongly aligned with the AAAS recommendations and was only lacking discussion of the utilization of modeling and simulation in it's strategic plan and Chair's Welcome (Appendix D, Table D.1). It was also recommended that the Department of Biological Sciences include references to modeling and simulation on either the Chair's Welcome, strategic plan page or as a key aspect for student outcomes on the undergraduate program pages.

The AAAS (2011) goals for content and skills attainment were again compared to the course curriculum as outlined by the program schedules from all the Biological Sciences program offerings. It was determined that the department was lacking programs that highlighted ecology and evolution as stated above when compared to peer institutions (Appendix D, Table D.2). The recommendation was the creation of programs or curriculum to address such a deficiency. This recommendation was supported through the faculty interviews that often stated the same (Appendix G, Table G.1).

Goal 2: Improving alignment with the University of Delaware general education goals.

The department initially performed curricular mapping to the University of Delaware's General Education goals. However, no recommendations were given for how to improve alignment. Through the analysis of curricular mapping it was determined that the core-required courses aligned significantly with reasoning quantitatively, computationally and scientifically (Appendix E, Table E.4). The connections were obvious to the faculty who participated in the mapping. Second best alignment came from the category that included critical reading, argument analysis and constructive ideation (Appendix E, Table E.1). Most faculty viewed the scientific process as the key source of alignment (Appendix G, Table G.4). Moderate alignment occurred with the category of written and oral communication, as in most courses lab reports, written assignments and presentations are necessary (Appendix E, Table E.2).

The least extent of alignment occurred with the category of critically evaluating the ethical implications of what students say and do (Appendix E, Table E.3). Based on this, it was recommended that faculty consider having an ethics component within their course to improve its eligibility for satisfying certification and listing as a General Education course as noted in Figure 2. This recommendation is important given that faculty interviews revealed that most do not take into account general education goals when designing and teaching their courses. Ethical considerations were the least included concept or skill in course content as determined by faculty interviews and survey results that shows the skill of understanding the relationship between science and society as scoring the lowest in priority or frequency of inclusion (Appendix G, Table G.2).

Figure 2: List of recommendations and artifacts for evidence for goal 2 improvement.

Artifact Used in Analysis:	Recommendations:
• Artifact 3: Vision and Change Analysis • Artifact 4: General Education Curriculum Mapping • Artifact 5: General Education Alignment with AAAS • Artifact 7: Faculty Perceptions	• Have course instructors consider including creative ideation and ethical implications • Certify courses that satisfy General Education requirements • Advertise such courses as options for non-majors or as efficient option for life science majors

Improving the outcomes for goal 2 should include better alignment with the University of Delaware General Education goals. Evidence for the recommendations can be found in the listed artifacts.

The Department of Biological Sciences can benefit from aligning and certifying courses as satisfying General Education. Doing so would increase course exposure, enrollment and utility. It may also be possible to decrease the number of courses required outside of biology in each degree program. If the courses within biology satisfied General Education goals and were therefore certified and listed in the course catalogue as such, the load on students would lighten and free up time for a greater number or higher-level biology courses. Students could also use the new found time to enroll in courses relevant to their future careers.

Goal 3: Improving the quality of scientific content and skills in the planned and taught curriculum.

Based on the faculty discussion and surveys, I concluded that certain courses would benefit from instructional professional development, pedagogical change, or possibly sequence repositioning so as to offer a greater benefit to the students. As previously determined from the peer alignment, recommendations were already in place for program restructuring and course dispersion. However, the interviews offered more information on individual courses and faculty perceptions of course sequence and opportunities for improvement as noted in Figure 3.

The interviews with faculty shed light on the sentiment of where and/or when students should be gaining the knowledge and skills recommended by AAAS. The general consensus was that the students should be exposed to the content and skills very early on. As it appears in the alignments, the introductory courses already perform this job (Appendix D). They serve as the early points of exposure for students for content and skills in the life sciences. Faculty who teach the higher-level courses often thought it was not their place to pass on skills or generalized content as noted by the discussion as well as the survey showing more moderate inclusion scores in the introductory courses (Appendix G, Table G.3). Understandably these courses are of a greater focus and some content is not applicable. However, some faculty argued that the skills should be developed throughout the student's progression through the program. Skills should be introduced, and then honed to a fine talent by the time they have graduated by means of continual exposure.

Figure 3: List of recommendations and artifacts for evidence for goal 3 improvement.

Artifact Used in Analysis:	Recommendations:
• Artifact 2: Analysis of Peer and Aspirational Institutions • Artifact 3: Vision and Change Analysis • Artifact 4: Strategic Goals Alignment • Artifact 7: Faculty Perceptions • Artifact 8: Literature Review	• Begin new culture of advancing instructional development • Reconsider promotion and tenure requirements to include instructional performance or development • Create courses focusing on developmental biology • Consider following instructional models coming from integrated Biology & Chemistry for all introductory courses

Improving the outcomes for goal 3 should include increasing the quality of scientific content and skills development in the planned and taught curriculum. Evidence for the recommendations can be found in the listed artifacts.

The faculty interviews pointed to the need to allow time or support of instructional development. Those faculty members who had initial positive experiences with instructional peer review noted that it is not done as often anymore. The encouraging discussion topic for instructional development was the efforts put forth by the Center for Teaching and Assessment of Learning (CTAL). Most interviewed faculty had at least knowledge of the facility, many had used it for instruction or technology utilization improvement in the course and several noted the recommendation for contacting CTAL came from the department's administration (Appendix G, Discussion). Few faculty members showed no concern for instructional development, while some thought CTAL was too generalized for their greatest benefit. The most critical discussion occurred over the Department of Biological Sciences' lack of support either financially or by time release for instructional development. Many stated it seemed they were on their own time when it came to course and program review or pedagogical development (Appendix G, Table G.4). The three most important recommendations that emerged from faculty interviews and surveys are for the department to have a greater emphasis put on instructional development, include the efforts in promotion and tenure discussions, and support faculty that wish to develop their teaching either financially or through time release.

Chapter 4

IMPROVEMENT STRATEGIES RESULTS

Analysis for the results of the ELP were carried out using the strength, weakness, opportunity, threats (SWOT) method. According to Jeffrey Harrison, SWOT analysis is often the precursor to business industry decision-making (2010). To properly carry out SWOT analysis Harrison states it is necessary to have a complete review of the field's literature, in depth analysis of key data points and the input from experts in the field. In this ELP, the literature review is ongoing from the AAAS *Vision and Change* as well as the *Bio2010* documents, primary educational research on curriculum and pedagogy. Key data was examined from peer institutions, program requirements and scheduling, enrollment, curriculum mapping and publicly available lists of program goals and outcomes. The role of expert comes again from the AAAS as well as faculty.

The SWOT analysis is described below. For each improvement goal the strength, weakness, opportunity and threat are outlined and followed by the proposed recommendations.

<u>Goal 1: Creating a public profile and curriculum that aligns with peer and aspirational institutions and the national recommendations.</u>

The first goal of this ELP was to determine if the Department of Biological Sciences has most efficiently publicly advertised its goals and strategies for student success. Artifact 4 (Appendix D, Table D.1) showed the strength of the department was that the strategic plan and Chair's welcome aligned very well with the AAAS national recommendations as seen in

Figure 4. The websites strongly emphasized the aspects of applying the process of science, use of quantitative reasoning, the interdisciplinary nature of science, ability to communicate and collaborate with other disciplines, and the ability to understand relationships between science and society.

Figure 4. SWOT analysis of public profile and peer alignment

Strength • Previous Chairs Welcome and public profile aligned well with university and AAAS recommendations • Programs, majors and course requirements align well with peers • iBC pedagogy aligns well with AAAS recommendations	**Weakness** • Public profile missing goal of model and simulation use • Programs, majors and course requirements missing Ecology and Evolution as a focus • Course offerings lacking Developmental Biology
Opportunity • Strong interest and expertise in Developmental Biology • Chance to restructure Biotechnology B.S. • Incoming Department Chair	**Threat** • College of Health Sciences growth and strategic plan • Increasing student to faculty ratio • Biological Sciences strategic plan is timing out without replacement

As compared to the AAAS *Vision and Change* document, the public profile of the department aligns very well with the content recommendations. Though this is not the intended purpose of the content, the majors and required courses show the strengths of the department. As noted in the interviews (Appendix G), there is a major focus on cellular and molecular biology, this is confirmed by the majors and courses offered (Appendix B). The Department of Biological Sciences course offering also aligns very well with national recommendations

(Appendix D, Table D.3). The core-required courses cover the content recommendations from AAAS. The only missing aspect during the original analysis was that there was no match to the "Information Flow" content (Appendix D, Table D.3). However, the interviews with the core-required course instructional faculty showed that information flow was a concept covered throughout the course progression (Appendix G, Table G.4).

The biology curriculum goals have been analyzed as well for strengths, weaknesses, threats and opportunities as to how they align with peer institutions and national recommendations (Brewer & Smith, 2011). Analysis included the major offerings and individual course programming of each major offered by the University of Delaware Department of Biological Sciences. The main strength of the department's course requirements is in its alignment with peers. When comparing to the recommended peers such as University of Massachusetts, University of Pennsylvania, University of Pittsburgh, University of Maryland Baltimore County, University of Maryland College Park, University of Virginia and the University of North Carolina Chapel Hill, the University of Delaware offers comparable programs, majors, faculty sizes and general infrastructure to compete with regional institutions (Appendix B).

Another strength is in the department's course offering for introductory years. The integrated courses offered at the Integrated Science Learning Laboratory utilize a curriculum model that combines biology with chemistry throughout the two-semester progression through freshman year. The courses also offer small class sizes, placing a maximum of about 48 students per lecture section that allows for using more interactive pedagogies, which benefit students (Appendix F; Luckie, Aubry, Marengo, Rivkin Foos & Meleszewski, 2012), a topic that will be discussed as strength for Goal 3.

A weakness in the public profile is the minor exclusion of discussing how the department utilizes modeling and simulation (Appendix D, Table D.1). It was confirmed by faculty interviews however that the department does not actually provide many opportunities to use models and simulation in the core-required courses (Appendix G, Table G.3), so it is not just a public profile concern. It is a lack of the use of models and simulation in the instructional delivery of the curricula.

The weaknesses in the Department of Biological Sciences curriculum goals are relatively few. The majors offered lack an Evolution and Ecology aspect as seen in peer and aspirational institutions (Appendix D, Table D.4). Though there is decent coverage of the content as recommended by AAAS, most other peer and aspirational institutions have an Evolution- or Ecology-based major. As noted in the interviews, the Department of Biological Sciences at the University of Delaware is lacking in those courses (Appendix G, Table G.4). For example, the course BISC208 Introductory Biology II does have evolution and ecology as a major focus, however it is only about one-quarter to one-third the total course content, depending on the course design by the instructor.

Another weakness with in the Department of Biological Sciences undergraduate program is the lack of coverage for developmental biology. As discussed in the interviews, there is currently little offered by way of programs, courses and content for developmental biology. Yet it's weakness is seemingly ablated by the fact that the AAAS has not listed developmental biology as a key content area (Chapter 2, Inset). Yet, as noted in the interview, recent hiring has led to an increase in the number of faculty with research interest focused on developmental biology which would now be a strength of the department and therefore an opportunity to expand to offerings courses or majors in this domain.

The greatest opportunity the department faces is the introduction of a new Chair of the department in the winter of 2019. This analysis may aid in the creation of the new Chair's Welcome and Strategic Plan website. It is recommended that the new Chair's website and the department return to the goals that were listed previously and find a way to reference the goals of modeling and simulation that are occurring at least in some of the department's courses.

Another opportunity for the department is found in the current discussion of the restructuring of the abandoned B.S. in Biotechnology. The program was abandoned in 2014 due to lack of interest and low enrollment rates (University of Delaware, 2017b). When interviewing faculty, discussion of the topic was centered on how to enliven the program to meet the new demands for bio-informatics as computational reasoning is not often included in core-required courses (Appendix G, Table G.4). The artifacts contained within this ELP first suggested a reorganization of the majors, and possibly had an effect on the programs committee. Further recommendation from this ELP is to take advantage of the opportunity given the open Biotechnology degree and rename and re-structure it to cover the AAAS recommendations for information flow and match to peer and aspirational institutions (Appendix B, Table B.4).

According to Pevzner and Shamir classes in computational biology should be as standard in this decade as molecular biology was in the past. They state there is a need for students to understand and properly use bioinformatics tools, to avoid misinterpreting results from cut and paste bio-informatics programs (2009). It is analogous to not understanding statistics; wrong interpretations can be made from statistics if the underlying rules of the technique are not understood. A student versed in bio-informatics would be able to use, understand, and critically review others work for inherent flaws and create better informed decisions. The sentiment has been repeated in more recent publications that are still calling for inclusion of bioinformatics in undergraduate biology education due to the access of high throughput big data techniques such as whole genome sequencing and metabolomics analysis (Wilson Sayers et al., 2018). However, the method in which bioinformatics can be added is fairly difficult due to the nature of the material, the varying cultures clashes between biology and computing departments, the lack of infrastructure at universities and the lack of funding to improve these situations (Magana, J., Taleyarkhan, M., Rivera Alvarado, D., Kane, M., Springer, J., and Clase, K., 2014)

One large threat to success is that as of the writing of this document, the Chair of the department is currently an interim position and the Chair's welcome as well as some of the other departmental strategy websites have been disabled. Therefore, prospective students looking to be accepted to the University of Delaware or students already enrolled in the university as undeclared or university studies have no means to inform their decisions on whether to join the department majoring in biology. It is a missed opportunity to influence and attract incoming students.

A threat in the category of curricula and course offerings is 1) other departments from within the university of Delaware and 2) other institutions. One threat that stands out when looking at the figures from the problem statement is the increasing student population in the College of Health Sciences. The College of Health Sciences is currently expanding into new buildings with a clear plan for developing the college into a first class research and educational institution. The college is likely pulling students interested in the medical field from the Department of Biological Sciences. According to the College of Health Sciences 2017 to 2021 strategic plan, they college has grown it's undergraduate population by 34% since 2010.

Increased the number of undergraduate programs including an Applied Molecular Biology and Biotechnology program that would have competed directly with the discontinued Department of Biology B.S. in Biotechnology (University of Delaware, 2017c).

The College of Health Sciences also has created seven new graduate degree programs (four more projected by 2021). The faculty population has increased by 45% and that faculty has accounted for over $82 million of grant funding (University of Delaware 2017c). There is now need to refurbish the Department of Biological Sciences to attract more students through a different career path. External threats are other regional universities that have similar goals, but newer facilities and intact strategic plans focused on student success. One last threat is a compounded issue, first is the fact that the Department of Biological Sciences has not had continuous leadership to follow through with the initial program review recommendations.

Secondly, the strategic plan that was made in 2014 with about five years of planning for faculty retirement, hiring and modification of course offerings is now late in it's scheduling. It is now late in 2018, and the transitional leadership had made only slight headway into the implementation of the strategic plan. A ten-year period is the recommended interval for internal or external reviews as per the faculty handbook (University of Delaware, 2016), which should carry the department into 2022. The current strategic plan extends to 2019. There currently is no strong focus on the future of biology education past next year.

The University of Delaware Department of Biological Sciences has a strategic plan that was pulled from a national document 7 years ago. In the realm of Biological/Biomedical research it is best to reference documents no older than 5 years. The department's strategic plan is surely out of date. This can be contrasted to the newest strategic plan from the College of Health Sciences that has a focus towards 2021, again a 5-year plan that began in 2017. The

Department of Biological Sciences should be working now towards the next 5 years, however that opportunity will need to wait until the next Department Chair has reviewed the status of the department and created the next strategic plan, likely in another year or so.

The second threat from other universities is a generalized one. For example, other regional universities may have more stable leadership and well thought out strategic plan available for public viewing such as those from University of Maryland Baltimore County, University of Massachusetts Amherst, or Cornell University (Appendix B). The University of Delaware may fall behind these competing universities and colleges with a clear strategic plan and leadership in place to drive the faculty towards the goals. This threat is noted with the caveat that in time each university may have their own upheavals and it is difficult to determine when each competing university has undergone a performance evaluation either internal or external. However, in speaking with the newer faculty during the interviews (Appendix G, Table G.4), it was determined that the length of time since the last program review at the University of Delaware Department of Biological Sciences, as perceived by faculty, was conducted too long of a time ago for it to still be relevant and that this action is not typical of other institutions.

According to the published research on SWOT analysis, the method is used to help institutions identify resources and opportunities that would help move them towards an agreed strategy (Dyson, 2004). The University of Delaware department of Biological Sciences could use an agreed strategy that is shared publicly to create a culture of change that would benefit the department as well as the students.

Goal 2: Improving alignment with the University of Delaware general education goals.

The University of Delaware Department of Biological Sciences aligns well with a majority of the General Education goals (Appendix E, Tables E.1, E.2, E.3 & E.4). The goals and skills recommendations from the University of Delaware alluded to in Figure 2, have undergone a recent review and modification (University of Delaware, 2017a). The new goals include subsets of the larger concepts of critical thinking and evaluating, reasoning, communication, creative ideation as well as cultural diversity outcomes for student.

The goals the University of Delaware Department of Biological Sciences align strongly with the general education goals of critical thinking and evaluation as well as the computational, critical and scientific reasoning skills (Appendix E, Table E.1). The department curriculum and pedagogy also aligns well with two of three communication skills, those of written and oral communication (Appendix E, Table E.2). The alignment of these goals was supported by faculty interview (Appendix G, Table G.4) as well as a curriculum mapping exercise carried out by teaching faculty at a summer retreat held by the department. The larger curriculum mapping was broken down and more closely analyzed for only the core-required courses determined by the undergraduate programs and course requirement analysis (Appendix E, Tables E.1, E.2, E.3 & E.4). The SWOT analysis shown in Figure 5 pertains only to the six courses that were determined to be "required" by most Department of Biological Sciences undergraduate programs (Appendix B).

Two particular areas of weakness when aligning the Department offerings with the General Education goals include creative ideation and the consideration of cultural diversity. According to faculty interviews, written and oral presentations account for most methods of communication in the core required courses (Appendix G, Table G.4). It is also noted that considerations for working across culturally diverse groups applies to mostly lab group work in the four-credit courses. The students spend less time as individuals working across culturally diverse concepts, according to faculty perception (Appendix G, Table G.4).

Figure 5. SWOT analysis of alignment with General Education goals

Strength • University of Delaware has recently created strong General Education Goals • Created an outreach committee to work with departments • Department aligned well with critical thinking, evaluating, reasoning and communication skills from Gen Ed	**Weakness** • Department is less aligned with Creative Ideation skills goals for students • Department shows less evidence of cultural diversity outcomes for students
Opportunity • Overlap between AAAS goals and General Education skills goals • Chance to increase general audience interest in courses	**Threat** • Lack of interest in aligning and certifying courses with General Education goals • Loss of focus on ethical implications

The strength of the department aligning with general education goals does not necessarily come from a focused effort on alignment. It is a coincidental alignment, as noted in the interviews most faculty felt that if they were meeting the recommendations of AAAS they would be meeting most General Education goals (Appendix G, Table G.4). Also this has been shown in the analysis in Appendix F, the general education goals genuinely overlap well with the AAAS goals (Table F.1). Therefore by aligning well with the AAAS goals, the Department of Biological Sciences automatically aligns with most of UD's General Education goals. That means that with additional effort the department could take advantage of General Education alignment and have courses certified to satisfy the requirements.

Figure 5 also notes the opportunity found by the shear fact that the AAAS goals overlap greatly with the General Education goals (Appendix F, Table F.1). This is backed by the faculty perception. A majority of faculty stated they would prefer to design courses and pedagogical goals while referencing the AAAS recommendations, as they are more in line with STEM based courses than the Gen Ed goals (Appendix G, Table G.4). There is now an opportunity to make those small changes while the University of Delaware is currently focusing a large amount of time and energy through seminars, workshops and meetings to advance the agenda of cultural sensitivity and diversity awareness. The recommendation of including more ethics, as well as including programs to help students be more aware of culture and diversity within the curriculum in the department programs would satisfy General Education goals as well as AAAS. However, this does not seem to be a priority with the department as noted by faculty interviews. The recommendation could be brought to the attention of the incoming Department Chair for future consideration to address the lack of awareness and concern for ethical and cultural awareness.

The last poorly aligned section of the department curriculum with the General Education goals includes the goal “Critically evaluate the ethical implications of what they say and do”. I believe this is greater than just a weakness as the AAAS excluded as a concept the matters of ethics and responsible scientific communication. They were included under the umbrella of “Understanding the relationship of science and society” (Appendix F, Table F.1). And while the faculty discussed society in the interviews, only two directly addressed discussing ethics in their core-required course (Appendix G, Table G.4). There is a

Responsibility And Integrity In Science and Engineering (RAISE) course available for graduate students at the 600 level available as an elective. However, neither this course nor a 400 level equivalent is offered to undergraduates. Surprisingly, the course catalogue for spring 2018 shows that the RAISE course was cancelled for graduate students (University of Delaware, 2018) due to inadequate enrolment.

It seems then the best way to involve students in ethical inquiry and discussion is to include this content into the core required classes. There are resources within the University of Delaware such as the Center for Science, Ethics & Public Policy (SEPP) which offers a resource page full of activities for many scientific fields on ethical topics such as publishing and research, risks and safety, informed consent, animal rights, health care, policy, malpractice and so on (University of Delaware, 2018). In addition to the university resources, the Online Ethics Center (onlineethics.org) has over 570 case studies on ethical topics in the field of science and engineering, in class activities, multimedia resources and instructional materials to lead discussion and reflection (National Academy of Engineering, 2018).

As an example of means of implementation, I had applied for and received small project grant funding from SEPP for inclusion of ethics in a course I co-lecture, BISC625 Cancer Biology in 2016 (Appendix J). I utilized the SEPP resources to discuss topics such as humans as trial subjects, abuse of minority and susceptible populations, the Nuremburg trials, and quality of life discussions. The purpose is for the students to have a deeper understanding of ethical implications of their actions. Student understanding was assessed by grading the level of inclusion of ethical concerns in their written grant assignment.

Goal 3: Improving the quality of scientific content and skills in the planned and taught curriculum.

As seen in Figure 6, a strength within the department can be found in the delivery of instruction by the faculty who teach in the integrated biology and chemistry (iBC) courses. According to the faculty (Appendix G), those who have self-identified as teaching integrated courses have used most 21st century style teaching methods that align with the AAAS recommendations. The effectiveness of 21st century style teaching has been supported by myriad educational research publications (Hayes, 2006; Thompson, Chmielewski, Gaines, Hrycyna & Lacourse, 2013) as noted in Appendix H, the literature review of biology curriculum. These include active learning strategies, reflection journals, exam wrappers, which is the opportunity for students to reflect on the exam performance in particular, and several other methods of instruction that have shown evidence to be beneficial for student learning.

The University of Delaware offers exceptional instructional development through the combined effort of the Center for Teaching and Assessment of Learning (CTAL) and the Faculty Commons, which has been shown to be effective at increasing student learning outcomes (Wieman, Perkins & Gilbert, 2010). There is now dedicated space on campus for the delivery of tangibles for course design, pedagogy support, and technology assistance. Often there have been many faculty institutes that share information regarding pedagogy and assessment; I have attended three Summer Faculty Institutes. I also attended a winter institute called Redesigning Large Introductory Course (ReLIC) that focused on backward course design and implementation of active learning and efficient use of group projects to benefit student outcomes (Appendix I).

The department has done a decent job of advertising these events, however faculty's participation seems to vary depending on their assigned courses. When the faculty interviews are broken down by demographics, those faculty that teach introductory courses have taken advantage of the CTAL and Faculty Commons program more often. The faculty that identify as "research faculty" or those that teach higher level lower enrollment specialty courses, participate less often in teaching institutes, workshops and instructional development programming (Appendix G, Table G.4). There is ample opportunity for all faculty members to undergo effective instructional development by utilizing the excellent resources from CTAL and Faculty Commons.

During the interviews, the faculty expressed concern about the department being viewed as a service department by higher-level administrators (Appendix G). The increasing frequency of requiring BISC courses for several non-life science majors and university breadth requirement fulfillment is driving class enrollment increases. This often pushes course enrollments past 90 students per section. Faculty expressed concern in the interviews that they would not be able to create courses that focus on their research interests as they would be busy teaching larger enrollment introductory courses (Appendix G, Table G.4).

Figure 6. SWOT analysis of curriculum and pedagogy

Strength • CTAL offerings and Summer Institutes • Faculty Commons availability and workshops • iBC pedagogy aligns well with AAAS recommendations	**Weakness** • Department does not fully utilize CTAL and Faculty Commons programming • Course offerings lacking Developmental Biology
Opportunity • Incoming Chair can begin culture of advancing instructional development • Incoming Department Chair has the chance to engage with T&P Committee to change CNTT promotion and tenure culture	**Threat** • Large enrollment introductory classes do not permit for research topic focused seminar courses • Promotion and tenure guidelines focus on research success and pay less attention to teaching performance

The promotion and tenure issue is compounded by the current criteria for promotion and tenure that do not take into account the effort needed to improve instruction nor place high value on funded educational research nor actionable research projects, those projects that improve everyday instruction as opposed to published peer reviewed research (Appendix G, Table G.4). It seems that the Department of Biological Sciences recommends instructional development but has not truly institutionalized it. As evident by the faculty member interviews, the department merely recommends the CTAL and Faculty Commons yet does not account for time and effort, or reward instructional development efforts through merit pay, or promotion and tenure expectations (Appendix G, Table G.4). Though this may be the standard across a university campus, the Department of Biological Sciences could take the lead and start a new culture. Again, the incoming Department Chair has an opportunity to change this culture, however the power for changing the Department's promotion and tenure expectations resides with its P&T committee.

Limitations

To place the recommendations from this study into perspective it is necessary to discuss the particular limitations of the methods. For Artifact 2 (Appendix B) Analysis of peer and aspirational institutions, the institutions were selected based on regional limitations and faculty size as well as student body size and number of students enrolled in the life sciences. On occasion an institution was included on behest of the undergraduate program committee or the institution was referenced in the University of Delaware Department of Biological Sciences APR. This allowed for the inclusion of institutions such as Swarthmore, a small liberal arts college with a seemingly dissimilar student and faculty body, and UC Davis, which is not a regional competing institution. Similarly some institutions were excluded from the study as they were not considered competing institutions even though they are regional and of comparable size.

As an example many of the regional institutions such as James Madison University, William & Mary University, or George Mason University were excluded from the study as competing institutions for students in the Life Sciences since faculty or APR reviewing bodies as perceived them, most likely based on research funding. The inclusion of the stated institutions in the study was also influenced by current concerns such as those raised by President Assanis (2016) in his presentation to the trustees in which he lists current and hopeful peer institutions.

The limitations within Artifact 4 (Appendix D) Department of biological sciences goals alignment with AAAS recommendations, is that there is not one particular place to gather all the goals from the department. The student learning goals are pulled from various sources such as the Chair's Welcome website, the program descriptions from the Undergraduate Program website for each degree and the 2012 APR. This is therefore a composite of the goals, which can lead to some error. Depending on the role of the stakeholder, some goals may be of greater importance. I however felt it best to include several sources than just rely on one possibly limiting source.

Artifact 5 (Appendix E) focused on general education curriculum mapping, also has an inherent limitation when considering the outcomes and recommendations in that study. The mapping in that study is carried out by the faculty and is based primarily in faculty perception. While it is the best source for intent on skills coverage in a course, it is not a reliable one. The mapping was carried out based only in perception and not backed by evidence from the faculty by way of analyzing syllabi or course activities. If there was a follow-up study for more information on this topic in these courses, I would ask for a list from the faculty of instances in which skills were discussed, practiced, or assessed during the class meetings or search for similar evidence as a third party investigator.

Another similar limitation is found in the study of faculty perceptions (Appendix G). Again, the opinions and statements made in those interviews are to be interpreted as perceptions rather than facts. Secondly, although the faculty of the University of Delaware's Department of biological Sciences is roughly 40 individuals of varying rank, the faculty interviews consisted of a sample size of only seven. While this may be considered an adequate level of response to social science research methods such as interview, focus group and survey, it is noted several times in Artifact 7 (Appendix G) the small sample size whose perceptions may not properly represent the total population. Some perspectives may have been missed and others may have been over represented.

Perhaps one larger limitation of the study as a whole is the lack of student input. Since the focus of this study was analyzing the intended content and skills conferred upon students, they would be the largest body of stakeholders and the ultimate participants. While surveying graduates of the program would have shed light on the efficiency and effectiveness of the University of Delaware's Department of Biological Sciences, this study was not designed to obtain this data. However, this study provides the groundwork for future effort to solicit data from current students and alums to get their perspectives and inform future decisions.

Chapter 5

REFLECTION ON IMPROVEMENT EFFORT RESULTS

Reflecting on this project, I believe that it was a good start to addressing the stated improvement goals. Several analyses and alignments were performed, resulting in a number of recommendations. The intent of this study was to hand these recommendations over to the Department Chair and the Undergraduate Programs Committee, or any committee that had an interest in the findings. I would argue that overall, with the recommendations made in Table 2 below and the results of the alignments handed over to the Undergraduate Program Committee, the intent of the study was carried out. I feel it is important to recognize I was not in a position to institute any of these recommended changes. I primarily acted as a researcher and reporter.

Table 2
List of recommendations and supporting artifacts.

Recommendations	Artifact Used in Analysis
Create new strategic plan, public profile and Chairs Welcome emphasizing career paths	Artifact 2: Analysis of Peer and Aspirational Institutions Artifact 4: Strategic Goals Alignment
Increase focus on Ecology and Evolution content as well as utilization of models and simulation skill set	Artifact 2: Analysis of Peer and Aspirational Institutions Artifact 3: Vision and Change Analysis Artifact 4: Strategic Goals Alignment Artifact 7: Faculty Perceptions
Restructure the Biotechnology degree to include more bioinformatics or computational biology	Artifact 2: Analysis of Peer and Aspirational Institutions Artifact 3: Vision and Change Analysis Artifact 4: Strategic Goals Alignment Artifact 7: Faculty Perceptions

Have course instructors consider including creative ideation and ethical implications	Artifact 3: Vision and Change Analysis Artifact 5: General Education Curriculum Mapping Artifact 6: General Education Alignment with AAAS Artifact 7: Faculty Perceptions
Certify courses that satisfy General Education requirements	Artifact 3: Vision and Change Analysis Artifact 5: General Education Curriculum Mapping Artifact 6: General Education Alignment with AAAS Artifact 7: Faculty Perceptions
Advertise such courses as options for non-majors or as efficient option for life science majors	Artifact 3: Vision and Change Analysis Artifact 5: General Education Curriculum Mapping Artifact 6: General Education Alignment with AAAS Artifact 7: Faculty Perceptions
Begin new culture of advancing instructional development	Artifact 3: Vision and Change Analysis Artifact 4: Strategic Goals Alignment Artifact 7: Faculty Perceptions Artifact 8: Literature Review
Reconsider promotion and tenure requirements to include instructional performance or development	Artifact 3: Vision and Change Analysis Artifact 4: Strategic Goals Alignment Artifact 7: Faculty Perceptions Artifact 8: Literature Review w
Create courses focusing on developmental biology	Artifact 2: Analysis of Peer and Aspirational Institutions Artifact 3: Vision and Change Analysis Artifact 4: Strategic Goals Alignment Artifact 7: Faculty Perceptions Artifact 8: Literature Review

Consider following instructional models coming from integrated Biology & Chemistry for all introductory courses	Artifact 3: Vision and Change Analysis Artifact 4: Strategic Goals Alignment Artifact 7: Faculty Perceptions Artifact 8: Literature Review

Regarding program requirements, the research I gathered and recommendations I offered, seemed to be used in decision making that included BISC401 Genetics to be kept as a requirement while lessening the number of required courses for the B.A. degree. Artifact 2 Analysis of peer and aspirational institutions (Appendix B), was used by the Undergraduate Programs Committee and those responsible for instituting program change to determine that the course BISC403 Genetics be maintained as a core course requirement for the Bachelor of Arts degree as the program recently underwent a review and restructuring. The improvement resulted from the study requires students who wish to graduate with a B.A. in Biological Sciences to take BISC207 & BISC208, the Introductory Biology I&II progression and Genetics. The rest of the biology courses are open as electives. The undergraduate program committee determined that the majority of students in the B.A. program wishing to go onto medical, veterinary or dental schools should have a basic understanding of genetics.

This study has also been used to determine that there was a need for re-instating the virology course that has been absent for years since the mass faculty retirement that occurred within the past 10 years. It can be found in the course search at the Registrar's website as BISC467 Seminar: Introduction to Virology for three credits. Artifact 2 Analysis of peer and aspirational institutions, is still being used as a resource to determine if Microbiology or any other related courses such as Immunology are acceptable requirements for future program restructuring.

The program change initially went against the recommendation to create greater rigor in the B.A. degree by requiring more STEM courses to benefit those headed to medical school, but now I realize that recommendation was a bit limiting. There is the greater population of students who like biology and wish to be in the field yet are not headed to graduate or medical schools. My focus at the time was blinded by my own pre-conceptions of why students were interested in the program. I can see that the B.A. is a good fit for students headed to medical school, which has a competitive application process that puts greater weight on G.P.A. and M.C.A.T. scores than depth of knowledge of biology, as well as being a good fit for students that wish to have careers surrounding science but with creative outlets such as advertising and science writing. By opening the curriculum up the Department of Biological Sciences can accommodate a more diverse student population.

In regards to the goal of creating recommendations for course content and skills alignment, I did have the added benefit of being an instructor of two core-required courses at the University of Delaware. I instruct BISC207 & BISC208, the introductory biology course progression. During my research into instruction and pedagogy, I was exposed to the concepts of 21st century skills and student-centered instructional strategies. I found myself reflecting on my own practices within my courses and began to be influenced by my own findings. It was about this time as well that the department hired two faculty members into the Interdisciplinary Science and Engineering (ISE) Laboratory and took over teaching the Integrated Biology Chemistry (iBC) courses. The courses I was teaching at the time were and are still heavily rooted in student-centered learning: there is a great deal of time and effort put into group work, active learning, student reflection. These courses are taught by a team of instructors, preceptors and T.A.s. I was assigned to teach the larger non-integrated courses that met in lecture halls and relied more heavily on the sage on the stage format. I began to implement the practices I learned in the ISE lab as well as my own reading and document analyses. I began using clickers in class for discussion topics and had students complete coursework in groups during lecture hours.

As a result of the ReLIC institute and similar workshops offered by CTAL and Faculty Commons, I used backwards design to create new syllabi that put the expected student outcomes from AAAS *Vision and Change* front and center, as well as included recommended small exercises utilizing creative ideation (Appendix I). It was at these workshops when also I recognized the importance of transparency of student learning outcomes expectations. I learned it was best to explain to the students why they were carrying out an exercise, so they had a purpose in mind when participating in active learning. I hope these concepts catch on in the other core-required courses as well as the electives. But I know that it will be up to the other instructors to recognize the benefit of instructional development. If the incoming Department Chair and the promotion and tenure committee changed the focus of milestones to include instructional development, there would then be great incentive for change.

Having one and one half goals executed and or acted upon, as the peer alignments were used to determine course requirement by the departmental Undergraduate Programs Committee and personally utilizing better pedagogical practices from goal three, I would like to see the other goal be so well received. However, I cannot determine at this time how they will be executed. The last goal I am referring to is the public profile the Department of Biological Sciences portrays. I had made recommendations as to how the Chair's Welcome and the student outcomes strategies plan could be restructured to align better with the national recommendations for student outcomes.

However most of those recommendations were made to improve the previous Department Chair's websites and we currently have an interim Chair who is focused on hiring the next Department Chair. Therefore she has not created a similar webpage. These recommendations are no longer valid or applicable. I would like to offer the review to the incoming chair, however that individual is not even named as of this writing. While they may take seat as planned in the winter of 2019, my goal is to share this recommendation with the department chair upon assuming this position.

Concerning course goal alignment with the University's general education goals, interviews with the faculty showed that they are not particularly concerned about it (Appendix G, Table G.4). Interestingly, most also thought the general education goals and AAAS goals overlapped by a great deal. My analysis showed that the curriculum left out one AAAS goal and general education goal that overlapped regarding science & society and cultural aspects, respectively (Appendix F, Table F.1). By providing the students opportunities to engage with issues about science and society, instructors can satisfy the ethical and cultural aspects of general education goals and have their course certified. One way in which I have included societal thinking in my biology courses is adding a myth-busting component to each section. I ask students what they have heard about a particular component from friends and family that are not strongly educated in the life sciences. Often the topics include the beginning of life, aliens, pan-spermy theory, cryptozoology or general misconceptions about evolution, ecology, nutrition and aging. By having the students present the questions, it draws them into the discussion.

I also use class time by have the students search for answers and critically think about their information sources based on the central questions of: Who wrote it? Who paid for it? And why? It often leads to discussions of agendas and hidden biases. As it stands, my courses may include a valid societal aspect, however as with other faculty, I have never considered having my courses certified to fulfill general education goals. It would also be a larger conversation as my course is the standard BISC207 and BISC208 that were handed to me by previous instructors with predetermine content. Changing status of the course would require those societal aspects to be implemented in several other sections of the course taught by three to four other faculty members, and that content would have to be voted on by teaching faculty. However, if the content were certified, this ensures that this type of content stays in it regardless of the instructor. This is something that would have to be brought up in faculty meetings and in the specific BISC207/208 faculty workshops.

However, as with every change to curriculum, there should be buy in from those in the practice as well as leadership showing strong reasoning with evidence and beneficial outcomes. For now the Department of Biological Sciences at the University of Delaware is missing that focus and leadership. I recognize that leadership is not always top down and the implementation of these topics, content and skills acquisitions can initiated by those of us in the trenches of teaching. It is an aspect that I will cover in the next chapter when reflecting on my leadership development.

Chapter 6

REFLECTIONS ON LEADERSHIP DEVELOPMENT

I began this program with the career goal of teaching in higher education. In complete honesty, I applied for the Ed.D. in Curriculum, Technology & Higher Education and when the letter said “Congratulations on your acceptance in the Educational Leadership program”, I initially thought there was a drastic error on my part in the application process. I later came to find that the new program was a condensation of the two previous curriculum and administration tracks with a leadership component engrained. It has been quite an experience since then. In the time it took me to complete the program, I have gone from guest lecturing, to teaching my own courses in vocational schools to instructing non-majors in biology at the University of Delaware, to teaching Introductory Biology to life science majors, and now instructing electives at the 400 level. My responsibilities have expanded as much as my knowledge of instructional methods and pedagogy.

Once I planned to become a science instructor, I sought out Higher Education and Teaching Certification (HETC) at the University of Delaware and was first exposed to pedagogy and faculty roles. I see now the information was just flying over my head, as it takes a manner of repeated exposure and practice to be able to utilize the tools that are handed to you in the course throughout the Educational Doctorate program. Coursework in the Ed.D. program furthered my developing understanding of methods of instruction. It began with gaining historical perspective on curriculum and the introduction of student centered learning, active learning practices, flipped classrooms, educational technology and the importance of evidence-based decision making.

That last process of evidence-based decision-making has been a staple of my career as a science researcher, as I experimented in cellular and molecular biology. Yet it was a stretch for me to make the connection between evidence and implementing instructional or curriculum change. However, that fact was driven home as my committee continued to argue for an artifact requiring me to dive into the educational research literature and find the evidence for proper and/or improper curriculum implementation. In that research, I found how useful active learning was, even if only a small component of the whole course and the wealth of knowledge hidden in *CBER Life Sciences*, to the point that I hope to publish in such a journal soon in my educational career.

When someone's recommendations are not heeded, it can feel like a personal insult. While I never expected my research to be the beacon of reason in the fog of curriculum change, I thought that my recommendations were reasonable. In addressing the question of how the Department of Biological Sciences could better compete with peer aspirational institutions in the areas of curriculum and degree programming (see Appendix B for details), I recommended that the curriculum of B.A. degree be adjusted to hold greater rigor by including more higher level STEM course such as Calculus and Genetics. Soon after my recommendations were handed in as completion of the BISC833 Independent Studies course in the fall semester of 2015, the Undergraduate Program committee went the opposite direction, thus removing core required STEM courses from the degree requirements.

From that result, I realized that I have to occasionally sit with my opinions and play the devil's advocate. I need to ask, "how would this recommendation negatively affect someone?" The truth is, during the creation of that recommendation I was completely ignoring a large population of stakeholders in the B.A. program, the students uninterested in graduate school. I was imparting my own bias of being a product of graduate school onto the curriculum change recommendations. I now realize that I often need to find the original purpose of the program and use that as the theme of the program review. I had not asked the proper questions from those who had created the program or were then running it. I did not find the broader purpose of the B.A. degree, I focused on a subset of the population that were choosing the B.A. track as a consequence of the selection process for Medical and veterinary schools. Dr. Buttram would be offended I had not listened better in class.

Throughout the doctorate program it has also been obvious that a great deal of importance has been placed on evidence based decision-making. That evidence just as with science should not be subjective. In the process of data collection, I carried out interviews with faculty who teach core-required courses. The information collected from the faculty most likely reflected their perspective on the state of the courses they teach. On several instances, the faculty made statements on choosing to include or not include some technology, instructional method or assessment type (Appendix G). Though the perspective they gave may have been based on years of instruction, it likely was not based in evidence. When reading through the educational research it was obvious that lecture is the worst type of instruction, assessments should be varied and feedback should be given as often and quickly as possible for student success. Yet as seen in Appendix G, some faculty are not aware of the evidence and act in opposition to existing recommendations.

Improvement of my skills as a partner in the Department of Biological Sciences did not originally come from my colleagues in the department. My first reflection on my role as colleague came as I defended my proposal. My original proposal painted the department in a poor light. I focused too greatly on the negatives, the falling number of Biology majors. I lost site of the increasing enrollment in BISC207 & BISC208 Introductory Biology courses. I painted the portrait of a department losing students to the College of Health Sciences, not taking into account the growth of that college simply meant there were more options for the students and that could benefit the University of Delaware as a whole, including our department. My committee brought it to my attention that I would be alienating some members of my department before I ask them for help in running a miniature program review. I was offending the stakeholders prior to asking them to participate, casting blame before finding out pertinent information. Through the program I continually kept in mind that I may be asked to present this information to a group of stakeholders, so it is best I find a way to present the less than stellar results without blaming or judging, being sure to look for the positive within the institution.

One benefit of carrying out the ELP improvement strategies I have personally had is an increased networking capability. I have met with faculty in my department and had discussions with others that had interest in researching and improving the curriculum. I continue to have connections with individuals in CTAL, university administration, faculty in other departments such as chemistry, philosophy, business and entrepreneurship, and even a contributor to the AAAS *Vision and Change* document.- Dr. Harold White Professor Emeritus from our own University of Delaware Department of Chemistry and Biochemistry.

Yet the greatest benefit I have received from this program is the knowledge that I will forever be a student. I have joined the Center for the Integration of Research, Teaching and Learning (CIRTL) program that focuses on education research projects as a part of the scholarly activity of its participants. Through CIRTL faculty and graduate students learn of methods that improve undergraduate education. They offer career development workshops as well as instructional workshops and learning communities at UD. It's through national programs like these that I plan to continue my development and education. CIRTL programming allows for funding of small actionable education research projects similar to those carried out by graduate students in the Ed.D. program. I plan to continue to reflect upon my instruction and compare it to evidence based best practices from publications such as *CBE Life Sciences.*

My future career as an instructional faculty member will not stagnate with decades of monotonous lectures. My favorite part of instruction is the interaction with students and the art of teaching. My background in cellular and organismal research shows that I have an inquisitive mind. I plan to focus that inquisitive reflection onto my own practices. I wish to still run research, publish and present the findings; the subject will be science education. My main areas of interest include best instructional practices, student engagement, and administrative support.

As I reflect on leadership, I can look back at the several versions I have been given in my tenure at the University of Delaware. I was first hired into a research position that was under a transformational leader Dr. Cindy Farach-Carson. She was always focused on her employee and student growth through experiences and change. She welcomed individuals that took on increasing responsibility. That style worked very well for me, I received my only promotions through her leadership. After Dr. Farach-Carson left for a provost position at another university, leadership for me for a brief period came from other faculty and staff members less so from my supervisor. I had found mentors that encouraged my growth as an instructor and helped me wedge myself into the faculty of the University of Delaware Department of Biological Sciences.

While my personal mentors were acting as leaders, the department went through a loss of symbolic leadership. The department lost its culture and camaraderie, things in the department got a bit oppositional. Through my business leadership course I recognized that the work culture was not being supported by the gatherings that happened frequently under previous leadership. Mixers, holiday parties and functions were being removed from the calendar, as was food and beverage from the standard required meetings. This lead to a general sense of malaise expressed by a few that remembered "the good old days". That is not to say that mixers and holiday parties are key assets of all work culture, but it was key to that culture previously in place. It would have been wise to replace the lost items with a new culture, supported by the Department Chair. Workplace cultures can be focused on successes, legends or by repeatedly expressing the need for innovation or experimentation.

A form of leadership that resonated with me returned when the Department Chair, which happened to be my supervisor's position, was taken up by an interim that brought with her a leadership style that was again transformational. Dr. Robin Morgan was dealing with the same pressures as previous chairs yet still expressed that interest in employee, faculty and staff growth. Somehow she abated the oppositional forces and was in the process of creating a coherent strategic plan referenced in this ELP from 2014 to 2019. Her work was not complete when her leadership talent was recognized and she was appointed to the position of interim Provost then Provost within the span of one academic year. It seems the acts of listening, comprehending, compromising and planning for the future are the hallmarks of effective leadership.

As I continue to develop my leadership skills, I would likely nurture those qualities that have worked for me personally as well as those that worked to advance my former supervisors.

I recognize that most of my examples are top down versions of leadership and that leadership can sometimes come from the bottom. As input is needed, committee members can work to functionalize a group of individuals to accomplish a goal. I hope to be a functional committee member of interests that I find important and beneficial to my organization and bring about the evidence-based change that would benefit students and faculty fellows. I see myself first focusing on pedagogy and curriculum. It will take some time for the mantle of Doctorate of Education to sink in, but I have already seen where my expertise has benefitted other faculty and courses, namely BISC625 Cancer Biology and SOCI413 Race and Health where I have given input on course syllabus creation and content recommendations. I aspire to be a resource for faculty and administration in my department. I also hope that my recommendations will generate needed discussions and contribute significantly to the improvement of the quality of the department's programs.

REFERENCES

Assanis, D. (2016). *State of the University*. Presentation September 29-30, 2016, University of Delaware. Retrieved from https://www1.udel.edu/vp-sec/MeetingMaterials/09-29-30-2016/

Bowen, G. A., (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, *9(2)*, 27-40.

Brewer, C. & Smith, D. (2011). *Vision and change in undergraduate biology education* (1st ed.). Washington, D.C.: American Association for the Advancement of Science.

Dyson, R.G. (2004). Strategic development and SWOT analysis at the University of Warwick. *European Journal of Operational Research.* 152 (3), 631-640.

Freeman, S., Allison, L. A., Black, M., Podgorski, G., Quillin, K., Monroe, J., & Taylor, E. (2014). *Biological science*. Boston: Pearson.

Harrison, J. (2010). *Essentials of Strategic Planning in Healthcare*. Chicago, IL.: Health Administration Press.

Hayes, W. (2006). *The progressive education movement: Is it still a factor in today's schools*? New York, N.Y.: Rowman & Littlefield Education.

Holm, B., Carter, V. C., & Woodin, T. (2011). Vision and change in biology undergraduate education: Vision and change from the funding front. *Biochemistry & Molecular Biology Education, 39(2)*, 87-90.

Krippendorf, K. (2004). *Content analysis: An introduction to its methodology* (2nd ed.). Thousand Oaks, CA: Sage.

Little, M. D. (2013). Embrace vision & change. *American Biology Teacher, 75*(6), 368.

Luckie,D.B., Aubry, J. R., Marengo, B. J., Rivkin, A. M., Foos, L. A., Maleszewski, J. J. (2012). Less teaching , more learning: 10-yr study supports increasing student learning through less coverage and more inquiry. *Adv. Physiol. Educ. 36*. 325-35.

Magana, J., Taleyarkhan, M., Rivera Alvarado, D., Kane, M., Springer, J., and Clase, K. (2014). A Survey of Scholarly Literature Describing the Field of Bioinformatics Education and Bioinformatics Educational Research. *CBE Life Sci Educ*. 13, 607–623.

Medina, S. R., Ortleib, E., & Metoyer, S. (2014). Life science literacy of an undergraduate population. *American Biology Teacher, 76*(1), 34-41.

Mulnix, A. B., & Vandegrift, E. V. H. (2014). A tipping point in STEM education reform. *Journal of College Science Teaching, 43*(3), 14-16.

National Academy of Engineering. (2018). *Online Ethics Center for Science and Engineering*. Retrieved from http://www.onlineethics.org/ .

National Research Council. (2003). *BIO2010: Transforming Undergraduate Education for Future Research Biologists.* Washington, D.C.: National Academies Press.

Pevzner, P. and Shamir, R. (2009). Computing Has Changed Biology—Biology Education Must Catch Up. *Science*. 325 (5940), 541-542.

Thompson, K. V., Chmielewski, J., Gaines, M. S., Hrycyna, C. A., and LaCourse, W. R. (2013). Competency-based reforms of the undergraduate biology curriculum: Integrating the physical and biological sciences. *CBE—Life Sciences Education, 12*, 162–169.

University of Delaware. (2016). *Faculty Handbook.* Retrieved from https://facultyhandbook.udel.edu/handbook/34-academic-program-review .

University of Delaware. (2017a). *General Education | General Education*. Retrieved from http://sites.udel.edu/gened/ .

University of Delaware. (2017b). *Undergraduate Programs: Department of Biological Sciences*. Retrieved from http://www.bio.udel.edu/undergraduate-programs

University of Delaware. (2017c). *Strategic Plan 2017-2021.* Retrieved from http://chs.udel.edu/wp-content/uploads/2017/11/Strategic-Plan-2017-2021.pdf

University of Delaware. (2018a). *Office of Registrar: Course Search-Query "BISC Spring 2018".* Retrieved from https://udapps.nss.udel.edu/CoursesSearch/

University of Delaware. (2018b). *Center for Science Ethics & Public Policy Resources*. Retrieved from http://www.sepp.udel.edu/resources.html

University of Delaware Department of Biological Sciences. (2006). *Academic Program Review 2006: Undergraduate Program*. Newark, DE.

University of Delaware Department of Biological Sciences. (2012). *Academic Program Review 2012: Undergraduate Program*. Newark, DE.

University of Delaware Department of Biological Sciences. (2014). *Strategic plan 2014-2019. Supplement to Academic Program Review 2012.* Internal Document.

Wieman, C. E., Perkins, K., Gilbert, S. (2010). Transforming science education at large research universities: a case study in progress. *Change*, *42*, 7–14.

White, M. D., & Marsh, E. E. (2006). Content analysis: A flexible methodology. *Library Trends*, *55*(1), 22-45.

Wilson Sayres, M.A., Hauser, C., Sierk, M., Robic, S., Rosenwald, A.G., Smith, T.M., Triplett, E.W., Williams, J.J., Dinsdale, E., Morgan, W.R., Burnette, J.M., Donovan, S.S., Drew, J.C., Elgin, S.C.R., Fowlks, E.R., Galindo-Gonzalez, S., Goodman, A.L., Grandgenett, N.F., Goller, C.C., Jungck, J.R., Newman, J.D., Pearson, W., Ryder, E.F., Tosado-Acevedo, R.w,, Tapprich, W., Tobin, T.C., Toro-Martínez, A., Welch, L.R., Wright, R., Barone, L., Ebenbach, D., McWilliams, M., Olney, K.C., Pauley, M.A. (2018). Bioinformatics core competencies for undergraduate life sciences education. *PLoS ONE.* 13, 6.

Appendix A

ELP PROPOSAL DOCUMENT

Introduction

Taken into account that biology is the study of life and lectures and teachings on life have been ongoing since Plato and Aristotle (Freeman et al., 2014). Between this point and the 19th century not much had changed in biology education. While the other arts and humanities began to grow with a stronger focus on human experience, the idea of the learners experience seemed less important in biology. Though early on there were dissenters to the common authoritarian role of the educator. Socrates preferred a much more involved student that actively and critically reviewed and answered the questions of life. John Locke and John Dewey argued for a better system of learning during their lifetimes, which spanned from 17th to 20th century, respectively (Hayes, 2006). But the roots of biology teaching were stuck in medical field that had a greater emphasis on training or conditioning, than to allow for free thought. Biology only really began to grow with the advent of greater technology such as microscopes which expanded biology into many smaller fields. Microscopy brought about cell and germ theory, Darwin and Wallace emphasized evolution and ecological succession. The 20th century brought the genetic age with Watson, Crick and Franklin. But one thing remained unchanged, the education of students in these disciplines stagnated as authoritarians lectured and students listened. The status quo was stimulus and response or assign and test, the argument being that hard science instructors should be the expert in the field and pass on knowledge, it was not necessary that they be great educators. It is this issue that we are still dealing with to this day. It seems much of the biology educator world has learned little from Socrates, Dewey or the other great educational progressivists. While a handful of biology educators have known for sometime that the methodologies in place are the least effective, many of us have been affected by several historical events that have molded the university setting. Stake-holding bodies of biology education have argued for reform for decades. This current work will highlight the most recent efforts to lead biology curriculum reform. To point, the author will focus on the Department of Biological Sciences at the University of Delaware as a case study to compare it's offerings to other peer and aspirational institutions and analyze the faculty perception of the alignment of the biology core curriculum to a recommended national standard.

Organizational Context

The University of Delaware is currently under new leadership since the appointment of a new president, Dr. Dennis Assanis, in July 2016. In his recent presentation on the state of the university to faculty, staff, at the board of trustees retreat, he restated the strategic plan of the university in the "Delaware will Shine" mission statement which highlights the importance of prioritizing to aspirational programs, so the university can be counted upon as one of the premier research universities and achieve scholarly productivity on par with top Association of American Universities (AAU) by 2025.

Dr. Assanis' presentation includes the following categories for university improvement: Enhancing the success of our students, building an environment of inclusive excellence, investing in our intellectual and physical capital, strengthening interdisciplinary and global programs, and fostering a spirit of innovation and entrepreneurship (Assanis, 2016). These goals are similar to previous "Path to Prominence" mission, set to motion under the leadership of former UD President Harker. However there is more focus on comparing ourselves to a new set of peers that will pull the university into a new higher tier of peers through the creation of strategic themes and actionable strategic plans. Throughout these strategic plans the new president continually refers to "academic excellence", "exploring opportunities for operational excellence" and "optimizing use of instructional resources" (Assanis, 2016). With that in mind, it is prudent for all departments to conduct an internal review of their programs to show how they meet or exceed national standards or identify an actionable plan for dealing with gaps between current programs and the national expectations.

The University of Delaware Department of Biological Sciences has previously undergone two academic program reviews (APR) within the past 10 years. The APR of 2006 noted the strong effort of the faculty of that time to include a quantitative biology component to all biology majors that required "curricular revision, increased affiliation with other departments, e.g. Mathematics, Physics and Computer Science, and new faculty recruitment" (University of Delaware Department of Biological Sciences, 2006). This effort was driven by the publication of the National Research Council's (2003), *BIO2010: Transforming Undergraduate Education for Future Research Biologists.* To that end the department created course sections of math classes that incorporated biological models and the Biological Data Analysis course BISC643, with the help of funding from HHMI for curriculum creation and publishing of the textbook for the course created by University of Delaware Department of Biological Sciences faculty. Following the 2006 APR an effort was also initiated to incorporate interdisciplinary programs into the Department of Biological Sciences. This effort led to the creation of the Integrated Science and Engineering Laboratory, now known as Harker Lab. Courses hosted within Harker Lab must follow a strict policy of being heavily integrated with another science or engineering discipline.

The second APR in the department's 10-year history was performed in 2012. It is this APR that first introduced the AAAS' (2011) *Vision and Change* document to members of the department as the new national standard for science education. It is noted in the 2012 APR that *Vision and Change* put an emphasis on having faculty view students "as active participants, not passive recipients, in all undergraduate biology courses" (Brewer & Smith, 2011), and to "think beyond instructional strategies, assessments, disciplinary boundaries, and definitions of science literacy and who can learn science" (University of Delaware Department of Biological Sciences, 2012). Though these concepts were being developed by the Department of Biological Sciences prior to the 2011 publication of *Vision and Change*, the APR admits that it is the current national standard and that any life science department should meet these standards.

Demographically the Department of Biological Sciences currently has roughly 620 undergraduates listed as majoring in either the B.A. or B.S. programs (Academic year 2015-2016). As a reference, the department has 4 undergraduate biology majors: B.A. Biology; B.A. Biology Education; B.S. Biology Cell, Molecular & Genetics; B.S. Biology Pharmaceuticals. Data pulled from the departmental website shows that there are also 36 faculty members which include tenure track, non-tenure track, and secondary appointment. It is uncertain if this includes adjunct faculty as none are listed as such on the website. The mission statement of the department according to the website, includes statements on students learning content from molecules, to cells, to organisms and ecology. The website also states the students will learn the valuable skills of scientific inquiry, critical thinking and problem solving, and “background essentials” for informed decisions on science, technology and environment. The mission statement rounds out by stating that the above knowledge and skills will prepare students for future study in graduate school as well as careers in “health professions, environmental science, law, biomedical ethics, genetic counseling, journalism, and public health” ("Undergraduate Programs : Department of Biological Sciences", 2017).

Organizational Role

My role in the Department of Biological Sciences at the University of Delaware has been fluid. While I have served a number of roles within the department, my current title is a Research Associate II with instructional and administrative responsibility. As an instructor, I have and will continue to teach the Introductory Biology I & II courses, as well as breadth requirement fulfilling non-major 100 level courses. My status as an instructor allows insight in the content of the department’s required introductory courses.

In my administrative responsibilities I can be called upon to perform manual labor and/or tasks requiring intellectual and organizational abilities. In the efforts to complete the coursework for my Ed.D., I have committed a semester’s worth of time and energy in assisting the Undergraduate Program Committee by acquiring the list of required, selective and elective courses from peer and aspirational departments, shown in this proposal as artifact 2. This data was useful in changing the status of several courses and optimization of prerequisites and co-requisites for program completion for B.A. and B.S. degrees.

This proposal comes as an extension of that study and attempts to dive deeper into the curriculum, pedagogy and assessment offered in the required classes in the Department of Biological Sciences. The audience of this study will be similar to that of artifact 2, the Undergraduate Program Committee, Undergraduate Program Director and several faculty administrators, such as faculty senate members, and Departmental Steering Committee members. The department chair may also have input and investment in the study as Academic Program Reviews will be included in the analysis and faculty perception of the curriculum will inform recommendations for curriculum reform implementation. The recommendations resulting from this study will be shared with the Department Chair who is likely to discuss it with the stakeholders in the department, most likely faculty and graduate students involved in instruction. Conducting this study will support my own aspiration to serve as an educational leader in the department.

Problem Statement

The University of Delaware Department of Biological Sciences, as well as many other peer and aspirational university's biology or life science departments, is tasked with a difficult proposition. Firstly, in the current research-funding environment, many faculty are losing grants and the undergraduate demand for careers in academia and industrial research is waning (Holm, Carter & Woodin, 2011). This leads to a transition from 75 percent or greater research workload to a majority teaching workload for many faculty. Secondly, even though the number of undergraduates majoring in the biological sciences seems to be on the decline, the biology courses enrollment is as strong as ever (data not shown). The growing student population in the College of Health Sciences is now driving the demand for more biology courses. Thirdly, a recent spate of transitions in the University from 4 presidents, 2 deans and 4 department chairs (incoming 5th chair predicted by Summer 2018) as well as what may be labeled as bulk faculty retirement and departure has led to a turnover of the department's teaching faculty over the last ten years. All these factors can lead to a loss in the translation of the goals and strategic plan of the department molded over the same 10-year period in which the 2 previous APRs occurred. Thus the problem statement of this proposal is as such: Is the curriculum in the Department of Biological Sciences at the University of Delaware still standing up to the national standard as provided by the AAAS *Vision and Change* document as it pertains to content, skills, pedagogy and assessment?

I will compare the content, skills learned in the required courses and most selected/recommended electives at the University of Delaware that are considered most relevant to undergraduates to the most recent theoretical framework created by highly regarded authorities on the subject of biology education. The document entitled *Vision and Change in Undergraduate Biology Education, A call to Action* is a summary of the findings and discussions from a national conference hosted by the American Association for the Advancement of Science (AAAS) in association with National Science Foundation (NSF), National Institutes of Health (NIH) and the Howard Hughes Medical Institute (Medina, Ortleib & Metoyer, 2014). The NSF, NIH, and HHMI are three of the major funding bodies in biology education as well as for national basic biology research. The journal, *Science*, published by the renowned AAAS, is one of the most well regarded journals in the field with the 12th highest impact factor of all biomedical journals. These national organizations have the power and influence to make changes in biology curricula at a national level. When they speak everyone listens. The demands on current life science and biology departments listed above, as well as the stigma that most life science courses are taught in a classical (A.K.A. boring) lecture style with an emphasis on rote memorization, required a reconsideration of how the life sciences should be taught, the learning outcomes associated with them, and the key concepts any student undertaking the life sciences should understand thoroughly (Mulnix & Vandegrift, 2014). The document itself is over 60 pages long with several chapters and many thought provoking. However, the following excerpt from an editorial from the National Association of Biology Teachers President Mark D. Little (2013) captures few key student outcome goals and concepts:

> "…. for a student to be biologically literate, he or she needs to have an understanding of five core concepts. These are (1) Evolution, (2) Structure and Function, (3) Information Flow, (4) Pathways and Transformation of Energy, and (5) Systems. The report calls for these core concepts to be integrated with core competencies and disciplinary practices, including (1) the ability to apply the process of science, (2) the ability to use quantitative reasoning, (3) the ability to use modeling and simulation, (4) the ability to tap into the interdisciplinary nature of science, (5) the ability to communicate and collaborate with other disciplines, and (6) the ability to understand relationships between science and society."

It is with this in mind that I will review, compare and critique the Department of Biological Sciences official documents such as APR's, mission statement, course descriptions, offerings and listing of required courses for several undergraduate programs as well as the University of Delaware General Education goals to determine the extent to which the department is meeting the goals of the *Vision and Change* document as well as the University of Delaware's general education goals. In an effort to validate that information, faculty interviews will be conducted to determine if the Department of Biological Sciences is upholding the efforts outlined in the 2012 APR for student learning, skills transferal, pedagogy and assessment as perceived by faculty.

Improvement Goals

The improvement goals for this study are fairly simple. By conducting this study, I will identify the extent of which the biology curriculum, as perceived by faculty, matches the recommendations of the General Education student outcome goals as well as those from the AAAS *Vision and Change* document through well informed guided faculty interviews and focus groups. However, in the event of the perception of the curriculum to be found as lacking in content, skills, pedagogy or assessment evidence by the faculty, I will make recommendations for improvement strategies in the hopes that the faculty will make the changes and take into account the goals for all biology graduates from our department. This aspect should be completed within one year of the start of the study, potentially by summer or early fall semester 2017.

Table A.1. *ELP Artifact List.*

	Artifact	Type	Audience	Description	Action Steps	Plans for IRB	Time-line	Status
1	ELP Proposal Document	Plan	Ed.D. Committee	Defines the problem and lists my planned solutions.	None	N/A	Winter 2016	Com-pleted

2	History, Benefits and Limitations of Curriculum Change	Lit Review	Biology Undergraduate Committee, Ed.D. Committee	Literature synthesis on biological sciences curriculum and pedagogical history, advancement and limitations with evidence for proper implementation of change		N/A	Fall 2017	Begun
3	833 Macro-Curriculum Review	Docu-ment /Data Analysis	Biology Undergraduate Committee	Review of Required, Selective, Elective courses, Majors and mission Statements from UD Depts. and peer as well as aspirational depts.. Analysis and recommendations for advancement of the department	Reviewed by Undergrad. Program committee and recommenda-tions taken in consideration.	N/A	Fall 2015	Com-pleted
4	897 Strategic Goals alignment	Docu-ment Analysis	EDUC 897, Bio. Department	Deeper analysis of the UD Dept. of Biological Sciences mission statement and how it aligns with the AAAS Vision and Change document Criteria for Biology graduates		N/A	Spring 2016	Com-pleted
5	Compariso n between AAAS Vision and Change Criteria to UD Gen Ed criteria.	Docu-ment Analysis	Ed.D. Committee/ Biology Dept.	Comparison for alignment of AAAS Vision and change document criteria to Gen Ed Criteria. May be useful to Biology Dept. for future undergraduate committee meetings as well as validation of adherence to AAAS criteria.	Listing criteria and grouping to determine if all some or none of the criteria from AAAS satisfy UD Gen Ed. Then narrative on reasons for inclusion, exclusion, results	N/A	Spring 2017	Com-pleted

6	Focus on *Vision and Change* in 2012 APR	Docu-ment Analysis	Ed.D. Committee/ Biology Dept.	In depth analysis of the *Vision and Change* document for components of import as to how the document informs student learning, success, pedagogy, departmental, university and career goals noted in the 2012 APR		N/A	Fall 2017	Com-pleted
7 / 8	Faculty Interview and Focus Groups		Ed.D. Committee/ Biology Dept.	In depth study of curriculum from several required, selective, elective courses for Biology majors.	List evidence/lack of evid. for content and skills criteria from AAAS. Express results by class or section, discuss possible recommenda-tions for greater inclusion of AAAS criteria.	Re-view sprin g 2018	Begin Winter 2018, comp-letion spring 2018	Begun

__**Artifact table and Narrative**__

Depending on the results of analyzing the department's mission statement relative to the AAAS document or the university general education recommendations, I will offer steps for the department as a whole to take towards aligning itself more with the funding bodies. The department's leadership is open to receiving recommendations that are intended to support the goal of aligning its course requirements to the local (UD General Education) and national (Brewer & Smith, 2011) visions. The recommendations arising from this ELP study will be shared and discussed with the department chair, Undergraduate Program Committee and other stake holding individuals in the administration of the department.

The artifacts presented below will be completed to gather evidence about how the University of Delaware's Department of Biological Sciences program aligns with the national standard, and consequently aid in the development of recommendations. The topics of interest include biology curriculum as it pertains to course offerings and content, pedagogy and assessment will be compared to those recommended by the *Vision and Change* document (AAAS, 2011) from the most well respected and largest funding body of science education in the United States.

Artifact 1: ELP Proposal.

The ELP Proposal Document is a narrative of the work I plan to complete through the ELP II and ELP III portion of the Educational Leadership Doctorate program. This proposal states the problem that exists at the University of Delaware Department of Biological Sciences and lists my action plans as artifacts. It also describes the organizational context and my role in the University of Delaware Department of Biological Sciences. This document shows the current efforts of the department to utilize evidence based educational research to keep the curriculum and methods of instruction up to date with peer and aspirational institutions and attempt to improve student-learning outcomes. The ELP Proposal document is intended to guide all work to be completed, in some instances artifacts were modified as more data or resources became available.

Artifact 2: Literature review on the history, advancement and limitations of biology curriculum and pedagogy.

This artifact will inform most of the following artifacts and narratives. It will serve as the basis of understanding for all decisions, recommendations and methodologies that will follow.

Artifact 3: Document/data analysis created by coding out information from many University of Delaware peer and aspirational institutions.

Similar departments of biology or life sciences websites were researched for the list of courses that are required, selective or strongly recommended electives. Further information gained from the websites, include demographic data such as lists of majors, faculty size, and student body size as well as mission statements that will be used in later analysis to determine if the peer or aspirational institute also aligns with the AAAS documents recommendations for content and skills for biology graduates. In this document recommendations were made for adjusting the University of Delaware course requirements to align with peers. The Undergraduate Program Committee has already used this document in the discussion and resolution of changes to the course requirements. Initially, these two documents were used to identify peer institutions, moving forward artifact 7 will rely on the information from artifact 3 to determine which faculty will be interviewed. Only faculty that instruct courses that have been determined by artifact 3 to be required biology curriculum classes will be included in the sampling for interview and focus groups.

Artifact 4: Strategic Goals alignment, second source of evidence on record for student learning goals and skills as determined by the University of Delaware Department of Biological Sciences.

In this artifact, the mission statement and "Chairs Welcome" of the Department of Biological Sciences website was compared to the AAAS document. The results from that study showed there were some gaps in the departments mission statement that did not address the ability to use modeling and simulations as recommended by the AAAS document. Though it is known that mission statements are idealized and often lack the particular strategies or plans as to how the goals shall be attained. It is for this reason that a more thorough investigation of the curriculum should be performed as proposed by this educational leadership portfolio. Through the progress of the ELP, this artifact will also serve to inform artifact 7, the faculty interviews. The data gathered from artifact 4 will direct the tone or topics of the guided interviews performed in the completion of artifact 7. The interview and focus group conversation will include the facts that the department mission statement does not include some of the recommended goals of the national standard as well as the importance of meeting the departmental goals in individual courses or as a whole in the required coursework.

Artifact 5: Comparison of General Education (Gen. Ed.) recommendations at the University of Delaware to AAAS recommendations.

Artifact 5 will make for a better discussion on the alignment with the department goals and strategies with both the general education and AAAS goals that will take place in completing artifact 7, the faculty interviews. On the University of Delaware General Education website (sites.udel.edu/gened/) are 5 highlighted objectives expected of a University of Delaware graduate. These goals include the ability to read critically, communicate effectively, work collaboratively, critically evaluate, and reason quantitatively (University of Delaware, 2017a). Comparing the General Education goals to the AAAS documents goals should again make clear the gaps between the status quo and the national standards at the university level. Similar to the effect artifact 4 will have, artifact 5 will help to create the guide for dialogue of the interview and focus group conversation with faculty for artifact 7.

Artifact 6: Document analysis of *Vision and Change,* the national standard as a stand-alone document as well as its role in the Department of Biological Sciences 2012 Academic Program Review.

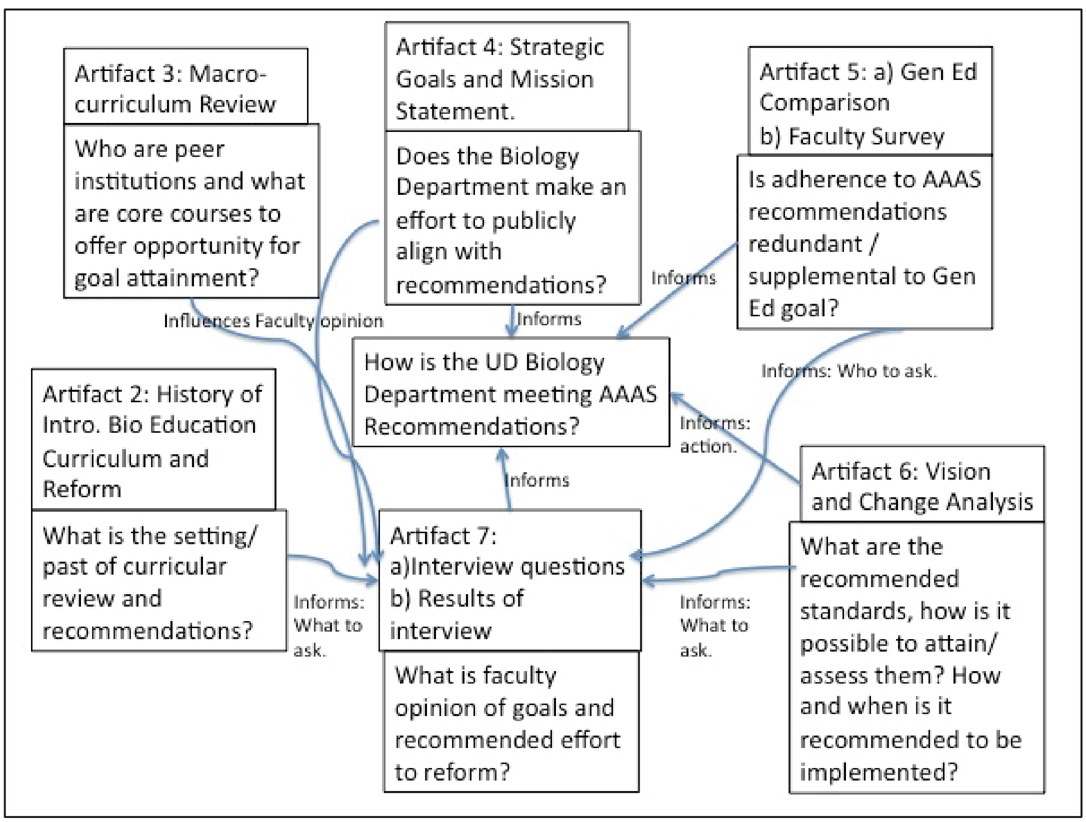
The AAAS *Vision and Change* document is a compendium on the state of science education. In this document, the most revered funding bodies in science education have laid out the current issues in biology curriculum. It also contains the vision and mission for creating a curriculum that does the most benefit to an undergraduate student in the life sciences. It is however not just a fantastical policy. It is grounded in evidence and strategies for successful student learning, pedagogy and assessment. Artifact 6 will be a comprehensive summary of all the strategies, rubrics, assessments and goals and will be the greatest base for conversation points in the faculty interviews to be completed in artifact 7. The tangible results of artifact 6 will be an outline for the interviews and focus groups.

Artifact 7: Faculty interview and survey.

Artifact 7 will consist of an in depth guided discussion aimed at soliciting some faculty members' perceptions as to how well the content, skills, pedagogy and assessment recommended by the AAAS are presented to the undergraduate students in the department as stated in artifact 4. Faculty to be invited to interview will be any that have taught within the last two years BISC207 & 208 Introductory Biology Courses, BISC305 Cell Biology, BISC401 Molecular Biology of the Cell and BISC403 Genetics. This course selection is based on the required lecture courses for both the B.A. and B.S. degrees in biology. The topics of discussion will be determined by completion of artifacts 2, 4, 5 and 6, and an interview protocol will be developed to guide the discussion. The methodology used in artifact 6 will be determined from the body of literature on qualitative analysis of documents. Full texts, such as Krippendorff's (2004) and journal articles such White and Marsh, (2006), which in many ways is a simplification or review of the Krippendorff text (2004), and Bowen's (2009) primer on the methods of qualitative analysis will inform the protocol for analysis of the interview recording and transcripts. In most instances, these texts and journals note a multi-step process. Firstly, sample the relevant text that in this case will be the transcripts of interviews from several faculty that instruct required biology courses. Secondly, unitize the text into quotes, examples or statements. Then thirdly, contextualize the information according to the circumstances or setting in which they take place (an introductory biology course) for either showing evidence or not of content or attempts at skills transfer. If time constraints are too critical, a smaller sample of the representative population of the faculty willing to participate will be used. The interviews or focus group discussion will lead towards finding whether or not the faculty felt as though they have conveyed the content or transferred the skills to the students, explore their attitudes towards the current pedagogy and assessments as well as possible reform. As above, the focus groups/interviews will be recorded and transcribed, then unitized and coded for evidence or lack thereof transfer of content and skills.

Overall this artifact is intended to be an effort to go deeper than artifact 4 has. As well known, the mission statement is often considered a sky-high aspirational statement, while the actual workings of the department may be a slight or even a far departure from the mission statement. This artifact will be more of a program evaluation or examination of the extent to which the department's mission statement and universities General Education goals translate into the goals of the individual required courses. Most of the recommendations for improvement of instruction, pedagogy and assessment will be coming from this artifact.

Below is a concept map of the artifacts of how they inform one another and lead to the interview of faculty members to gauge the alignment of the University of Delaware Department of Biological Sciences curriculum to the AAAS national recommendations.



References

Assanis, D. (2016). *State of the University*. Presentation September 29-30, 2016, University of Delaware. Retrieved from https://www1.udel.edu/vp-sec/MeetingMaterials/09-29-30-2016/

Bowen, G. A., (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, 9(2), 27-40.

Brewer, C. & Smith, D. (2011). *Vision and change in undergraduate biology education* (1st ed.). [Washington, D.C.]: American Association for the Advancement of Science.

Freeman, S., Allison, L. A., Black, M., Podgorski, G., Quillin, K., Monroe, J., & Taylor, E. (2014). *Biological science*. Boston: Pearson.

Hayes, W. (2006). *The progressive education movement: Is it still a factor in today's schools*? Rowman & Littlefield Education.

Holm, B., Carter, V. C., & Woodin, T. (2011). Vision and change in biology undergraduate education: Vision and change from the funding front. *Biochemistry & Molecular Biology Education, 39*(2), 87-90.

Krippendorf, K. (2004). *Content analysis: An introduction to its methodology* (2nd ed.). Thousand Oaks, CA: Sage.

Little, M. D. (2013). Embrace vision & change. *American Biology Teacher, 75*(6), 368-368.

Medina, S. R., Ortleib, E., & Metoyer, S. (2014). Life science literacy of an undergraduate population. *American Biology Teacher, 76*(1), 34-41.

Mulnix, A. B., & Vandegrift, E. V. H. (2014). A tipping point in STEM education reform. *Journal of College Science Teaching, 43*(3), 14-16.

National Research Council. (2003). *BIO2010: Transforming Undergraduate Education for Future Research Biologists.* National Academies Press.

Thompson, K. V., Chmielewski, J., Gaines, M. S., Hrycyna, C. A., and LaCourse, W. R. (2013). Competency-based reforms of the undergraduate biology curriculum: Integrating the physical and biological sciences. *CBE—Life Sciences Education*. 12, 162–169.

University of Delaware. (2017a). *General Education* | *General Education*. Retrieved from http://sites.udel.edu/gened/

University of Delaware. (2017b). *Undergraduate Programs: Department of Biological Sciences*. Retrieved from http://www.bio.udel.edu/undergraduate-programs

University of Delaware Department of Biological Sciences. (2006). *Academic Program Review 2006: Undergraduate Program*. Newark, DE.

University of Delaware Department of Biological Sciences. (2012). *Academic Program Review 2012: Undergraduate Program*. Newark, DE.

Wieman, C. E., Perkins, K., Gilbert, S. (2010). Transforming science education at large research universities: a case study in progress. *Change*. 42, 7–14.

White, M. D., & Marsh, E. E. (2006). Content analysis: A flexible methodology. *Library Trends*, 55(1), 22-45.

Appendix B

ANALYSIS OF PEER AND ASPIRATIONAL INSTITUTIONS

Context

The purpose of this paper is to research the information necessary to allow the Undergraduate Program Committee to make an evidence based decision on the direction of the course offerings in Biology. Many concerns have been raised with the conclusion of President Assanis' State of the University address. In that address he raises the question of "Who are the University of Delaware peers?" and offers several members of the American Association of Universities (AAU) as possible peers and aspirational institutions. Therefore this research will determine departmental peers, as well as determe aspirational programs for comparison. Secondly, some concern has been raised as to whether the Biology department should change its advertising/marketing towards undergrads in regards to majors, tracks, concentrations and/or specializations. Finally, I have been tasked with comparing the core class requirements and recommended electives in our major offerings. The result of this research should include my recommendations for action to be considered and discussed by the committee.

In the effort to identify the University of Delaware and Department of Biological Sciences peer institutions/departments many aspects will be considered. I will use geographic location within a reasonable distance. Most peer institution considerations will be on the east coast of the US with a major focus on the Mid-Atlantic and Northeast universities. A second consideration will be institution size. For this purpose, the overall undergraduate population will be determined. Also when possible I will research department size by either yearly student demographic data, or number of degrees conferred by the department. I will also determine department size by the number of Faculty listed in the directory, or again by yearly demographic data obtained through publicly published sources.

Using the departmental websites for each institution's undergraduate program, I will determine the basic tone or marketing strategy they are using to attract students to Biology. When possible, I will view the mission statement or opening website statement to determine how the program is described and whether they the publishers infer career direction or learning goals for the incoming students. The major concern will be if the publishers recommend a particular pathway to graduate school, professional schools, medical schools, or employment into the bio-technology workforce. Also, using available information I will determine the number of tracks, concentrations, specializations or majors offered by each department for the purposes of comparison to the University of Delaware, Department of Biological Sciences. The best effort will be taken to use the most comparable option to UD's B.A. and B.S. in Biology.

The final assessment and comparison parameter will be a list and/or map out of the core requirements for the equivalent B.S. in Biology from peer institutions against the University of Delaware's requisites and recommended electives. The major focus is on the Biology, Chemistry, Physics, and Math requirements for completion. Of special interest were how many institutions require genetics and/or molecular biology requirements. The data is represented by a table in excel format for quick reference.

Again, the final recommendations reflect the data mined from mission statements, major offerings and course requirements for completion. I expect to make recommendations on how the University of Delaware's Department of Biological Sciences can offer/present the majors to students as well as recommended career options or goals. I will also, hope to recommend changes to the tracks/majors or offer insight into collaborations with other departments for major offerings, as well as to avoid possible conflict with other departments. And finally, I will make recommendations for changes to the required and recommended curricula for the majors in the Department of Biological Sciences to align them more with similar offerings from successful peer institutions.

Results

<u>Peer Institutions</u>

Peer or aspirational institutions were selected based on previous University of Delaware administrative comparisons such as President Assanis' presentation to the Board of Trustees (Assanis, 2016) Annual Program Reviews (University of Delaware Department of Biological Sciences, 2006, 2012) (APR) or requested by the Undergraduate Programs Committee (UPC) for inclusion in the study. Table B.1 includes a list of the selected peer and aspirational institutions, and the reasons for selecting them as Assanis (2016), Biology APR or UPC.

Table B.1
List of organizations considered for comparison and reason for inclusion.

Peer or Aspirational Institution	Reason for inclusion in the study
University of Massachusetts Amherst	Assanis (2016), APR
Virginia Polytechnic and State University	Assanis (2016)

University of Pennsylvania	Assanis (2016)
University of Pittsburgh	Assanis (2016)
Virginia Commonwealth University	APR
University of Richmond	APR
Cornell University	Assanis (2016)
Princeton University (Ecology & Evolutionary Biology)	Assanis (2016), UPC
Princeton University (Molecular Biology)	Assanis (2016), UPC
Rutgers University	Assanis (2016)
Swarthmore College	UPC
Columbia University	Assanis (2016)
Georgetown University	UPC
SUNY Stony brook	Assanis (2016)
University of Maryland Baltimore County	APR, UPC
University of Maryland College Park	Assanis (2016)
Temple University	APR
University of Virginia	Assanis (2016)
University of North Carolina Chapel Hill	Assanis (2016)
University of Vermont	APR
University of California Davis	Assanis (2016), APR
University of Delaware	Self, means of comparison

Information about the program requirements was often taken from the institutions' respective departmental undergraduate advisement page. In most instances, the departments used for comparison were titled or synonymously titled biology or biological sciences, with few exceptions. Both Cornell University and Rutgers University have two colleges that utilize a shared advisement resource. Cornell uses the Office of Biology Advisement, in this instance the College of Arts and Sciences (CAS) and the College of Agriculture and Life Science (CALS), work off of the same advisement protocol for core classwork which was analyzed for the purpose of this study. Rutgers University's College of Art & Science (CAS) and College of Environmental & Biological Sciences (CEBS) is a similar entity.

Comparison of these program with others is difficult as the combination of the colleges leads to increased values for other parameters, such as number of offerings and majors, student enrollment, and faculty count. If possible it would have been preferred to isolate the CAS programs and compare the University of Delaware, but that proved difficult. Princeton University has recently divided its Biology Department in two, separating Molecular Biology from Ecology and Evolutionary Biology, for the purpose of this study, both have been included as separate entities with each department representing its unique majors and course requirements.

One of the other aspects of this study was to compare the University of Delaware to an aspirational program. For this purpose the University of California Davis (UCDavis) campus program was selected. As noted the UCDavis Biology program is not a department but a standalone college with huge enrollment, a large number of faculty, student enrollment and programs offered. However the program was selected as an aspirational one not for its quantitative numbers, as they match Cornell and Rutgers in this instance, but for the qualitative parameters which were not necessarily reviewed in this study.

As shown on Table B.2, the peer institutions the University of Delaware should be compared to programs housed in institutions with 10,000 to 30,000 total student enrollments, which take into account programs that have roughly half to twice the enrollment. Some institutions that have less than half the University of Delaware enrollment were included for informative purposes (Swarthmore College And Princeton University), yet direct comparison to those programs would be difficult due to the very low student to faculty ratio and emphasis in those programs to "one on one" learning. In the instance of Princeton University, all biology majors are required to have multiple semesters of faculty guided primary research. This is a feat very unlikely to replicate in a 17,000 undergraduate student institute such as the University of Delaware. As noted in Table B.2, the enrollment for Rutgers University was difficult to quantify as the institute has several departments that fall under the umbrella of biological Sciences.

Table B.2
Student population of peer and aspirational institutions.

Institution	**Size of student body**
University of Massachusetts (Amherst)	22,000 total undergraduates
Virginia Polytechnic Institute and State University	25,318 total undergraduates
University of Pennsylvania	10,406 total undergraduates

University of Pittsburgh	17,694 total undergraduates
Virginia Commonwealth University	23,962 total undergraduates
University of Richmond	2,983 total undergraduates
Cornell University	13,935 total undergraduates
Princeton University	5,391 total undergraduates
Rutgers University	n/a
Swarthmore College	1545 total undergraduates
Columbia University	8,410 total undergraduates
Georgetown University	7,636 total undergraduates
SUNY Stony Brook	16,480 total undergraduates
University of Maryland Baltimore County	11,379 total undergraduates
University of Maryland College Park	27,056 total undergraduates
Temple University	28,408 total undergraduates
University of Virginia	15,669 total undergraduates
University of North Carolina Chapel Hill	18,350 total undergraduates 2014
University of Vermont	9,958 total undergraduates 2014
UC Davis	27,728 total undergraduates 2014
University of Delaware	17,484 total undergraduates

The number of faculty is one of the final parameters in which a peer institution should be judged. Table B.3 shows the faculty number as determined by the respective universities' department of biology faculty web page. Persons counted as faculty include individuals listed at any level of professorship, instructors or instructional role, and/or laboratory coordinators. Adjunct faculty and those individuals with secondary appointment were often included yet noted in the data when included or excluded. Those individuals excluded were emeritus faculty, or those with administrative and/or staff position titles. Again, if the half to twice amount is applied to this parameter it would not rule out many institutions besides the previously mentions Rutgers and Cornell Universities, but that again being a complication of the conjoined colleges.

Table B.3
Faculty population by institution.

Institute	Size of faculty body
University of Massachusetts (Amherst)	44
Virginia Polytechnic Institute and State University	55
University of Pennsylvania	49 including adjunct
University of Pittsburgh	65
Virginia Commonwealth University	49
University of Richmond	28
Cornell University	Approximately 50
Princeton University	63
Rutgers University	Approximately 85

Swarthmore College	21
Columbia University	42
Georgetown University	32
SUNY Stony Brook	15
University of Maryland Baltimore County	41
University of Maryland College Park	62
Temple University	56
University of Virginia	47
University of North Carolina Chapel Hill	75
University of Vermont	45 including adjunct & secondary
UC Davis	148
University of Delaware	36 including secondary

Mission Statements

A tangential review of the peer institutions included the presence or absence of and main focuses of departmental mission statement. On most occasions the departmental home page offered a mission statement that was a multi-sentence paragraph. On fewer occasions the mission statement was found after brief website navigation either through the "Chair's Welcome Statement" site or found on it's own properly titled webpage. On the chance one was not found there were sometimes a "Careers" page or "alumni referral/testimony" page, in those instances the mission statement was best described as career oriented.

Each mission statement was analyzed for the main focus and after preliminary study, it was determined there was a handful of themes throughout peer institutions. Firstly, several statements spoke of educational goals of student knowledge of content or the ability of the institute's graduates to efficiently communicate scientific topics. Secondly, a greater number of statements included the topics of research or graduate school. Even though they may still be considered educational goals, it was separate and exclusionary enough to consider a differentiated topic. Many times this was brought up alongside the third and most common topic of career options. To note, though career options was the most often discussed topic in mission statements, there was hardly an instance were it or the others were the sole topic. Also of note, was the fact that many times career options were linked to particular majors or concentrations. Recommendations of majors or concentrations towards career options will be discussed in the next section where program offerings are compared.

Program Degrees, Majors or concentrations/Specializations

Degree offerings for peer institutions most commonly included Bachelor of Science and Bachelor of Arts, degree. The only institute that did not offer one of these choices was Swarthmore College. Understandably, Swarthmore College is a small liberal arts institute, so the only degree offered was a Bachelor of Arts. However, they still offered many majors pertaining to the field of biology.

For the most obvious reasons, Biology is the most offered major/concentration. Table 4B shows it was offered by 15 of the 19 peer institutions. In most cases Biology was offered alongside the more specified concentrations or majors. When biology is not an offered major, the institutions have dissected biology into more tightly defined majors. In most instances biology was broken into Ecology & Evolution (eight occurrences), Computational/Bioinformatics (six occurrences) or Molecular & Cellular (five occurrences) or some version of the two factions. In the extreme case of Princeton University, they have gone as far as to split biology into the two departments of Molecular Biology and Ecology & Evolution.

Table B.4
Frequency of degree offerings across all peer and aspirational institutions.

Major or Degree offered	Frequency
Biology	15
Ecology and Evolution	8
Computational/Bioinformatics	6
Molecular and Cellular Biology	5
Neurobiology	5
Environmental	4
Microbiology	2
Disease/Biomedicine	2

The other majors/concentrations are then offered alongside Biology or the two factions. Neurobiology is the most common with five occurrences, followed by Environmental biology with four, then Microbiology or Disease/Biomedicine with two offerings each. Biophysics, Genetics, and Biology Education are only offered once each out of all possible majors from peer institutions. This is not taking into account whether the major is offered for B.S., B.A. or both, as there are many permutations, but just as concentrations in general. So the sum total number of offerings is not equal to the total from the list of majors. There are a total of 57 offerings, yet the total in Table B.4 accounts for only 46, the difference is due to duplication of offerings in B.A. or B.S. degrees.

Information not readily ascertainable from the data is the fact that certain majors/concentrations or degrees are better suited to certain career paths. One repeated theme according to many mission statements or found in the descriptions of the majors, was that unless the institution offered a disease or biomedicine/pre-med major, the B.A. degree was heavily recommended for those interested in going to medical school. The B.S. degree was often advertised as being for those interested in careers in biotechnology or research based graduate school (M.S. and Ph.D.), with the majors determining which field of study or occupation in which it was to be specialized.
Along similar lines, individuals interested in careers or graduate school in biology education, the B.A. was again recommended. The statements often emphasized the broadened topics and extra curriculum in the humanities as better suiting the field of education.

Requisites and Co-requisites and Electives

For the purposes of quantifying the relevance of any particular class to the biological sciences, program course guides were analyzed for required courses (x), course that were selectable from a few within a grouping (s), heavily recommended (rec) or offered as an elective (e). These categories were then scored x = 3; s, s/rec, or rec = 2, e=1, blank space = 0, and the total of occurrences was tallied. To note, whether a course was listed as an elective or excluded from the course guide was the only difference between 1 and 0 points. It is assumed that if the course is a recommended elective it gets greater advertising and likely greater attendance than those not mentioned. In some cases a score of zero may be a simple oversight, or the institute may not offer the course, but the difference was not determined for the purpose of this study.

As seen below, there are classes that are canon in the major of biological sciences, introductory biology, general chemistry, organic chemistry, physics and calculus. Of these classes introductory biology is a requirements for both B.S. and B.A. degrees in biology, and all majors/concentrations/specializations offered by the institutions in this study scoring all possible 174 points. General chemistry I&II only have a few exceptions including University of Pennsylvania's computational biology major and Swarthmore's B.A. in biology. In those instances general chemistry I is either required or selected (173 pts) and general chemistry II is not required (168 pts). As noted, the University of Richmond does not list general chemistry as a required course, yet both the B.A. and B.S. degrees have introductory biology I&II listed as being integrated, so it is assumed the content of general chemistry is learned in those courses, that was equivalent of 3 points for each.

Similar to general chemistry, organic chemistry I has a stronger showing (146 pts) than organic chemistry II (128 pts). Exclusion of organic chemistry in total only occurs in University of Pennsylvania's computational biology program as well as the B.A. Biology degrees from the University of Virginia and UNC Chapel Hill. Of interest is the exclusion of organic biology from all Georgetown University (GU) offerings beside Biology, where it is at elective status. It is clear the course exists at GU, however its exclusion may be due to the content being covered in a different course, yet the details were not researched to determine at this point whether the content is completely absent from the programs.

In these peer institutions, Calculus I is more highly recommended than either of the organic chemistry courses at 147 points total. It is the highest scoring mathematics themed course in the study. Physics I&II both scored considerably lower than calculus at 125 and 106 point respectively. The major culprits in the decrease in points for physics I&II are the University of Pennsylvania and Georgetown University again, which do not have them listed for many majors. Also, many of the B.A. programs do not require physics I nor II. The required math course statistics scores 114 points, which puts it between calculus I and II as well as between physics I and II. In most cases, it is a combination of requiring calculus I, physics I and statistics, while calculus II and physics II more often fall to recommended or not described at all. One class that has been rising in the ranks from elective to canon is genetics. Scoring mid-pack with most of the math based courses genetics at 125 points separates itself from the other elective or select group courses, being the only one to score higher than 100 points. Genetics was represented as required, selectable, or a mentioned elective in all but 5 programs out of 57 total.

Often there was no difficulty in categorizing the courses that were grouped in microbiology, evolution, ecology or immunology. There was little cross listing or overlap naming with the courses. In some instances though, categorizing a course was difficult as some have names that span multiple groups. In the case of molecular & cellular biology, some distinctions and reconciliations had to be made. If a course guide listed the course as molecular or molecular & cellular biology it was included in this category. If it was listed as cellular biology it was grouped in the cell physiology category. If the course was labeled molecular & biochemistry it was categorized as biochemistry. In the chance it was listed as molecular genetics, it was placed under genetics.

And finally if it was listed as physiology, it was categorized as anatomy & physiology as the distinction between cellular or organismal was difficult to determine. The effect of misclassification of these course offerings may have a small effect yet, as it is, none scored higher than 100 points. Cellular & molecular biology, evolution and ecology were the highest ranking (95, 88 and 83 respectively) in this sub-100 grouping this correlates with the major offering of either biology or the factions of Ecology & Evolution or Molecular & Cellular Biology. In most cases, it was the corresponding major that contributed to upgrading one course from elective to recommended or required as logic would dictate.

Recommendations for the University of Delaware's Department of Biological Sciences

The first recommendation is for consideration of peer institutions. It is this authors recommendations that the peer institutions list should have excluded the University of Richmond and Swarthmore College due to small enrollment and too few faculty. Princeton University should have been excluded for similar reasons as well as their focus on individualized primary research. Any information gathered from Swarthmore College, University of Richmond and Princeton University should be considered anecdotal. I feel the data from these small private institutions would not be generalizable to a large, public, state university. When it comes to Rutgers and Cornell, this author feels it is best to err on the side of inclusion, as they are also regional, large, state universities similar in scope and student makeup to the University of Delaware.

When it comes to mission statements, the University of Delaware could benefit from advertising the majors offered towards particular career paths. In this sense, it is also recommended that any future advisement of students interested in medical school should be directed towards the B.A. in biology as in many instances, medical school are most interested in G.P.A. and MCAT scores. To benefit the pre-med students, the rigor should be brought up slightly as compared to the B.S., which would be recommended for those interested in biotechnology and research based graduate schools. Focus should also be put on MCAT test prep for pre-med students. It is this authors understanding that there is a lesser emphasis placed on physics and the higher-level biology courses such as cellular & molecular biology. While this may not sound like the best prospect for future physicians, it may lead to greater enrollment and retention.

The University of Delaware department of biological sciences should consider aligning itself with other peer institutions and separate the B.A. and B.S. into Cellular & Molecular Biology and Ecology & Evolution. This may be a long-term consideration as requisite coursework and instructional faculty that specializes in evolution would be needed, or research faculty with an interest in the endeavor would need a reconfiguration of workload.

Creation of a bioinformatics or computational biology should be considered. It should either be housed in biology or co-owned with computer sciences. Possibly as the program is building biology could be a concentration in the computer science B.A. or B.S. degree. The status of a similar program is difficult to discern from the current university website. There is a Computer Science B.S., but it does not show any concentrations or specializations.

Of special interest to this study was the requirement of genetics. It is this author's recommendation that genetics should stay a required course in almost all majors related to biological sciences. It scored higher than second semester math requirements such as calculus II and physics II and tied the score of physics I. It should be considered a requisite or co-requisite course whenever either calculus or physics are required in the life sciences. Further recommendations could be inferred from the data, but those are beyond the scope of this study as requested by the course designers and Undergraduate Programs Committee.

Further analysis may be done with the data collected for course requirement considerations or program review. However, the mission statements and student outcome goals will be discussed in another study on the University of Delaware Department of Biological sciences alignment with national recommendations.

References

Assanis, D. (2016). *State of the University*. Presentation September 29-30, 2016, University of Delaware. Retrieved from https://www1.udel.edu/vp-sec/MeetingMaterials/09-29-30-2016/

University of Delaware. (2017). *Undergraduate Programs: Department of Biological Sciences*. Retrieved from http://www.bio.udel.edu/undergraduate-programs

University of Delaware Department of Biological Sciences. (2012). *Academic Program Review 2012: Undergraduate Program*. Newark, DE.

Addendum to Appendix B:

Institute Name	Comparative Department	Mission Statement/Focus
University of Massachusettes (Amherst)	Biology	Learning Goals
Virginia Polytechnic Institute and State University	Biological Sciences	None found
University of Pennsylvania	Biology	No Mission/Career Oriented
University of Pittsburgh	Biological Sciences	No Mission/Career Oriented
Virginia Commonwealth University	Biology	Research/Grad School focused
University of Richmond	Biology	Focus on Undergrad Research
Cornell University	Office of Undergraduate Biology (Department of Biological Sciences in CAS)	None found
Princeton University	Ecology and Evolutionary Biology	Focus on Undergrad Research/student design the program
Princeton (con't)	Molecular Biology	Research and Career
Rutgers University	One Major through 2 Schools (Arts & Sciences; Environmental & Biological Sciences)	
Swarthmore College	Biology	Learning is Doing. Focus on communication, experimental design & career.
Columbia University	Biological Sciences	None found
Georgetown University	Biology	Focus on communication, research, and med school
SUNY Stony Brook	Undergraduate Biology	Focus on one-one research
University of Maryland Baltimore County	Biological Sciences	Small statement, careers are research or teaching-not medschool related.
University of Maryland College Park	Biology	Mostly about content but mention med-school
Temple University	Biology	BS for Research, BA for professional schools
University of Virgina	Biology	Career, teaching, healthcare and research
Univ of North Carolina Chapel Hill	Biology	informal, has a link to careers page
University of Vermont	Biology	Overall education goals, small class sizes, research and link to possible careers
UC Davis	College of Biology	Learning, Cooperation with faculty on research and engagement and leadership
University of Delaware	Biological Sciences	None, Welcome statement, focus on research and graduate school

Appendix C

ANALYSIS OF THE *VISION AND CHANGE* DOCUMENT

Context

The purpose of this in depth analysis of the American Association for the Advancement of Science *Vision and Change in Undergraduate Biology Education: a Call to Action* document is to inform the creation of a list of questions that will be used to gauge the faculty perception of how the content and skills recommended by the document are conveyed in their courses. The document has been analyzed in previous artifacts for it's main components as well as for the content and skills recommendations. To summarize the content, it has been determined by the AAAS committee that evolution, structure and function, information flow, pathways & transformation of energy and systems be covered and well understood by a graduate of a life sciences program.

Along side those materials the document argues that the student should attain the ability to applying the process of science, use quantitative reasoning, use modeling and simulation, tap into the interdisciplinary nature of science, communicate and collaborate with other disciplines, and finally understand relationships between science and society. This document will look through the post *Vision and Change* literature to determine if the recommendations have been widely implemented, as well as if there have been documented benefits from the recommendations. Limitations of the recommendations may also be discussed if found.

Previous analysis performed by the author on the University of Delaware Department of Biological Sciences content analysis and curricular mapping showed that the department already does a strong job of offering the recommended content within the core list of courses. It also puts forth a strong effort to include most of the recommended AAAS skills outcomes within it's own goals for student outcomes (Rohe, 2017). The question moving forward, is how can the department use the rest of the document to implement and assess learning and skills outcomes, as well as create an environment and culture of leadership that will value student centered learning and the importance of these outcomes.

Analysis

This analysis of the *Vision and Change* document will now go further into the recommendations and discuss the issues with re-envisioning the biology curriculum. The action items referred to in this section of the document include defining learning goals for the courses taught and aligning the assessments to truly assess student learning of the core concepts. It is highly (and repeatedly) recommended that faculty introduce fewer concepts, but go into greater depth to ensure student learning. One of the often reference publications that highlight this aspect is the 2005 article by Knight and Wood (2005). In that article they argue it is not a recommendation to cover less material and simply continue to lecture at length. However, Knight and Wood argue that more active learning should take place to teach students how to search for their own answers. They state "incorporating interactive engagement and cooperative work" can replace lecturing while still covering enough material by "demanding greater student responsibility for learning outside of class". Luckie, Aubry, Marengo, Rivkin, Foos & Maleszewski (2012) in a study on laboratory practices argues that students that explored their research topic deeply on their own, achieved deeper understanding of topics, techniques and the method of science.

Mirroring the findings of Luckie et al's lab study, in the lecture room Connell, Donovan & Chambers showed that having a student centered focus in the classroom such as didactic explanations of work sheets and think-pair-share was beneficial to student learning as evidenced by MAT scores and pre & post tests (2016). In the discussion the authors argue that content was gained outside of the classroom through "active, cooperative engagement with the material". There are also recommendations for steps to make the students want to learn the concepts. It is stated that relating the material to real world problems and examples that make it more relevant increase student learning. It is recommended that courses which plan to utilize problems or case studies implement complex case studies for complex structural knowledge, historical cases that have created a conceptual change, and knowledge generating cases that created new empirical data, which will all lead to a successful experience in problem solving and create a student that will continue to search for their own answers (Allchin, 2013).

As for the case study's effectiveness, it has been determined that the use of case studies in place of standard text reading and discussion in biology courses can significantly increase student test scores, in some cases from a failing to passing grade (Bonney, 2015). In fact the Bonney study found that the most effective case study, in terms of increasing student learning as determined by in class assessment, included a hands on portion when discussing osmosis (2015). To note though research has shown that there may not be a benefit to taking the active learning to such extremes as flipping the classroom, as it may only have as much of an effect as incorporating active learning into your more traditional classroom format (Jensen, Kummer & Godoy, 2014).

Finally there is a push to stimulate curiosity and passion in the students by demonstrating the love of science. It is noted that the instructional staff serve as the example of scientists to the students and if there is no passion for science in the authority figure, there may be no passion in science as a discipline or career. Research on the subject of generating passion in teaching is scarce, much less how passion can benefit science education. One meta-analysis review of literature used only 13 published articles from a decade worth of literature. Of those 13 articles, 2 were science related – one on science Olympiad participants and another on math education. That review showed that only a few authors clearly defined passion, but those that did often included the concept of identification and love for the activity. They also recommend that most studies inferred a needed support to nurture that passion (Ruiz-Alfonzo & Lorenzo, 2016). The authors argue that though there is a concept of passionate students doing better, there is not much empirical data to support that hypothesis. Most other literature is based on engaging the student, again with active learning activities. Other studies focus on student changing "attitudes" and "perception" towards science (Lee & Tsai, 2013; Brownell, Price & Steinman, 2013).

In regards to student engagement, the student response to a survey in the *Vision and Change* document notes that absolutely and without question, lecture is the worst method for engaging and impassioning students for science. However, in most instances for large universities there are an inherent issue with changing the format in which faculty teaches. Previously, the AAAS published the document *Science for all Americans* sighting a need for cognitive diversity which would expand the notion of who can be a good science teacher, or who can be a good scientist and the need to accept that students are not “us” (Rutherford, 1990). As noted in the other artifact on history of education, the current university model was created to deal with a surplus of post-WWII students and normalization of the college education to the majority of the population. The problem is, even though most instructors know better, they still have to regularly teach hundreds of students at a time, in the lecture hall setting and it is easy to fall into old patterns. *The Vision and* Change document show ways to fix the issues in the constrained settings faculty find themselves in.

The greatest recommendation is to have multiple assessments. AAAS argues that it is best not to rely on 2 exams per class, but to include many homework assignments and small teaching moments that offer students the chance to have incorrect thinking corrected in a low risk environment. And to that purpose, the AAAS document notes that the assessments themselves should not be limited to multiple choice and True/False items. *Vision and Change* notes that these types of exams or quizzes are easy forms of assessment to administer yet have the lowest potential to actually assess student learning. In fact some research shows that multiple-choice exams in introductory biology courses may be a hindrance to critical thinking and true student learning (Stanger-Hall, 2012). In this study the class was assessed differently between semesters. One semester took only multiple choice (MC) exams, the other took a mix assessment that included MC and short answer (SA). The mixed assessment group scored better and changed study habits that included a more efficient use of time spent on higher thinking. According to the author this was due to the expectation that SA assessments are harder (Stanger- Hall, 2012).

Short answers meet halfway up those scales as being the middle ground for ease of assessment and potential for assessing learning. It is also known that writing out explanations promotes knowledge integration (Linn & Eylon, 2011). So for larger class settings it is recommended to at least include a handful of short answers on assessments. Of course the greatest inhibitor for faculty inclusion of short answer is the time constraint, hence it's use in graduate schools when enrollment s small, but there is no possible efficient means to written exams in the 200 student enrolled courses (Pelaez, Boyd, Rojas & Hoover 2005).

The good news is recently advances in technology such as c-rater-ML can make scoring of constructed responses an automated system. The scoring system c-rater-ML has been shown to be statistically as similar to a human grader when used to score short answer explanations of biologic concepts (Liu, Rios, Heilman, Gerard & Linn, 2016). There was one instance of error due to a difference of language, that being an inferred synonym recognized by a human and not by the automated program. However it was once instance out of an eight-item test. The authors argue this could be corrected and minimized by having a large sample size for the purpose of building the model for responses (Liu et al., 2016).

The push from AAAS is for faculty to stop taking the easy way out and meet at middle ground early on for students. Technology has the means to make written answers to the large introductory courses, which means this thought provoking assessment style can now be introduced as early as first semester for sciences majors. The section devoted to assessments ends with the following action items: engage students as participants, use multiple modes of instruction, ensure classes are outcome driven and engaging, facilitate cooperative learning, introduce research experience as an integral component, use multiple forms and numerous assessments, give repeated feedback, view teaching as research – review, assess, improve and repeat.

To implement the shift in thinking from the previous content based ideology to the newer student-centered focus it is recommended by the AAAS document that next generation biology departments introduce the scientific process early and often in undergraduate courses. It states the process of science to be observation, experimentation and hypothesis testing. The University of Delaware Department of Biological Sciences currently runs freshman level Introductory Biology courses with a lab section that is slowly introducing the scientific method to students. The course often begins with observational labs, those that are similar to cooking according to the recipe. Often the instructors already know the outcome of the experiment and the students come to the conclusion by following step by step instructions to reach the end goal. This type of exercise is more than half of the make-up of lab section of Introductory Biology. Only 2 to 3 times a semester do the students engage in hypothesis driven experimentation. In those instances though, the hypothesis is limited to available resources and a handful of choices for variables that have already been tested on the subject with a known outcome to the instructor (Nauen & Kasprzak, 2017).

The recommendations from AAAS have been supported by recent research. One study comparing the traditional laboratory class to a version of the new recommended 21st century laboratory lead to a statistically significant increase in the normalized medical assessment test (Luckie, Aubry, Marengo, Rivkin, Foos & Maleszewski 2012). The 21st century version of the lab class in this study included 7 initial weeks of traditional introduction to basic lab skills and 2 “cookbook” exercises on polymerase chain reaction (PCR) and genome isolation. Each of these exercises were allowed another week for “repeat attempts until successful” results. Then the weeks 8 through 15 are independent investigations followed by a final paper, in lab final and symposium presentation (Luckie et al., 2012). *Vision and Change* documents student responses to “canned” labs as being ineffective and uninteresting. It argues that students prefer to be involved in the troubleshooting process, as opposed to the instructor and TA’s. Canned labs do not allow for creativity or the experience of experimental design or allowing students to understand that outcomes can be unexpected, opposite expectations or “messy” (Brewer & Smith, 2011 & Spell, Guinan, Miller & Beck 2014). The 21st century lab as recommended by Luckie et al., allows for failure and troubleshooting, with the expectation that they persist until completion.

A review article meta-analyzing publications from 2005 to 2012, showed that in that time period most research on inquiry based laboratories was occurring in upper level cell biology, genetics and molecular biology laboratories (Beck, Butler & Burke da Silva 2014). The authors conclude that inroads are being made into the inclusion of inquiry based laboratories in biology departments, however even though there may be a student learning outcome associated with it, there is issues with generalizing the results as the state there may be a “file-drawer effect” in which non-positive results may not be published (Beck et al., 2014).

While the canned lab is an efficient way to present the scientific method in a controlled environment, it does not quite reach the level of expectation of student learning concepts or competencies as recommended by the AAAS document. According to *Vision and Change* it is recommended that undergraduates be exposed to authentic research and hypothesis-driven experimentation with unknown outcomes, such as course-based projects, summer research, community based student research or other opportunities to learn science. One study carried out post-*Vision and* Change, showed that a summer course based research opportunity that focused on a single point mutation in cancer cells increased student understanding of the scientific method, data analysis, experimental repetition and collaboration as being important in the practice of science thinking (Brownell, Hekmat-Scafe, Singla, Chandler Seawell, Conklin Imam, Eddy, Stearns, & Cyert, 2015).

Vision and Change shows a link between research and lasting learning, noting a survey that showed 70% of students that participated in research piqued their interest in science related fields as well as prepared them for the expectations of graduate school (Brewer & Smith, 2011). The document also notes the link is even more prominent for minority and underrepresented student populations. The emphasis again being that early experience of research holds the greatest influence. Educational research continues to support the concept that authentic undergraduate research opportunities greatly impact underrepresented students. A study from California State University showed that high impact practices, such as authentic research increase graduation rates from 38% for those that had 0 high impact practices to 73% with just 3 or more high impact practices. A similar change was seen with non-underrepresented students but the effect was blunted from 55% graduation to 69%. (O'Donnell, Botelho, Brown & Gonzalez, 2015). It is strongly recommended by *Vision and Change* that all undergraduates participate in research within the first or second year with the greatest emphasis on this experience for students within the life sciences major. The document concedes that authentic research positions are limited and most likely not available to every life sciences major.

The issue for large universities quickly becomes apparent. For most institutions the size of the University of Delaware, there simply is not a large enough faculty base to support thousands of students participating in authentic research. Many students express interest early on and a handful can begin engaging in research. But even those handfuls of students require funding from the Principal Investigator (PI) to pay for the supplies being used by the undergraduate. Funding coming from major research funding agencies or foundations is getting more competitive on a yearly basis since official societies and federal funding foundations have been cutting budgets and funding smaller and smaller percentages of those that apply since 2009 (Hourihan, 2015). The National Institutes of Health, a major funding body in biological science and biomedical related fields have yet again had the budget cut by 3.4% between 2016 and 2017 (Hourihan, 2016). Therefore at the University of Delaware Department of Biological Sciences there are fewer PI's looking for undergraduate participants.

There is good news in biology education research though, one study showed that inclusion of students in a six day pre-college engagement STEM academy program lead to higher self efficacy, science identity, positive career expectancies and STEM retention (Findley-Van Nostrand & Pollenz, 2017). This program included high impact practices that included undergraduate research. Proving that it could be a small event that has a great impact and may not require multiple semesters of authentic research if the budget does not allow it. However, any program still requires funding and to that end one option the AAAAS document recommends is creating a stronger bond between the university and the bio-community in general.

Collaborating with private institutions, other universities and even state government offices allows the opportunity to expose students to research through data analysis, field work or internship. As noted in one case study, Wesley College, a small religious liberal arts college with little direct research funding, increased undergraduate exposure to authentic research through a 10 week summer internship program with it's partner institutions such as Delaware State University, the University of Delaware, Delaware Technical & Community College, Christiana Care health System, and Nemours/A.I. DuPont Hospital for Children. This system has greatly increased the capacity for undergraduate research at Wesley College without majorly restructuring the college's infrastructure or faculty/staff (D'Souza & Wang, 2012). It is noted that collaboration with industry and fellow public and private institutions has the added bonus of bringing the skill of science communication to the table as students learn to walk and talk science with veteran scientists as well as the general public, which is one of the recommended skills a graduate should have (O'Rourke, Crowley, Eigenbrode & Wulfhurst 2014; Thiry, Weston, Laursen & Hunter 2012).

Vision and Change offers a second recommendation to achieve similar results when compared to authentic research experience for undergraduates by working research into the curriculum by utilizing investigatory labs. The investigatory lab or Course-based undergraduate research (CURE) is a course paid for by tuition and possible lab fees (as done by the University of Delaware Department of Biological Sciences) outside of the required introductory lab classes. The investigatory lab is often later in the students career and incorporates a research faculties field of interest and research topic into the teaching setting. The example given by the AAAS document shows a genetics class that runs sequencing and cloning through the learning lab as opposed to using graduate students or outside companies to perform these somewhat menial and time consuming tasks.

However, as stated in *Vision and Change* the inclusion of students in the authentic research experience and setting can create the lifelong love of science needed for undergraduate success in the sciences. The benefit is not just for the students, in effect the PI gains a small army of technicians that are paying for the experience and add extra hands to the lab. A similar system is already in place for just about all Biological Sciences majors at the University of Delaware. However it seems the experience may be happening too late. As noted on the Department of Biological Sciences website, the sample schedule for a student graduating with a B.A. in Biological Sciences requires taking an investigative lab course in their senior year (University of Delaware, 2017). The bulk of the research in the field of biology education indicates that this is later than recommended to aid in scientific understanding and retention in STEM. The investigative labs could aid PI research by offering free use of the facility if the PI's allow the materials to be run through the instruments by the undergraduate students. This has been suggested by recent publication of faculty benefits from running CUREs. Aside from the benefit of multiple hands on their research, faculty enjoy running the CUREs, make a modest connection between research and teaching, add to the growing data sets of individual fields of study, publish more often, and can even help recruit researchers and attract funding which again all positively affect promotion and tenure decisions (Shortlidge, Bangera & Brownell, 2016).

Tuition paying students could also run less complex time-consuming methods such as tissue culture and sample preparation as well freeing up the time for the more experience graduate students and technicians that could then be placed on higher complexity tasks. There are some concerns however, as the student-centered focus would require that students learn the overall hypothesis of the PI's experiments and aid in the troubleshooting and running of protocols. And as noted by Shortlidge et al., faculty percieve the time, effort, complexity and uncertainty as science as being a challenge to students which can make the undergraduates resistant to research (2016).

Overall, there are great benefits and limitations to CUREs. There is a chance the students would not be able to use creative problem solving, or critical thinking. However it would be an excellent opportunity to learn and use the scientific method for purpose driven experimentation. There also is the danger that the student's efforts be viewed as exploitation. It is thus necessary to properly format the course to outline the learning objectives, expected outcomes and properly assess the student learning as with any course.

The final aspect of the *Vision and Change* document pertains to professional development for all biology faculty. It has been shown that even though there is a great push for faculty development, there is often resistance to change. Even after a faculty institute to instruct on how to teach student centered learning methods, a survey of participants had only 45% stating they would transition their teaching methods, while 25% actually showed evidence of doing so (Teasdale, Budd, Cervato, Iverson, Kraft, Manduca, McConnell, McDaris, Murray & Slattery 2011; Manduce, Iverson, Mcconnell, Bruckner, Greenseid, Macdonald, Tewksbury & Mogk 2014). The document calls for an increase in the training of doctoral candidates and post-doctoral fellows in methods of pedagogy and curriculum design similar to those taught in the Faculty Institutes for Reforming Science Teaching (FIRST IV) system. In this training, post-doctoral fellows are trained over 2 years on how to utilize student centered learning methods then mentors provide feedback. It is noted that the feedback is a very important part of the process as it allows practice and meta-cognitive review and then improvement for continued practice (Ebert-May, Derting, Henkel, Middlemis Maher, Momsen, Arnold & Passmore, 2015). The authors also reinforce that is best to have the future faculty create an entire course based on student centered learning than to show them how to include a piece on active learning or critical thinking alone. It puts a greater focus on learning outcomes and goals for the semester as well as aligning projects and assessments towards the outcomes (Ebert-May et al., 2015).

The AAAS begin by putting the onus on professional societies, the document recommends that organizations like Federation of American Societies for Experimental Biology (FASEB), American Society for Cell Biology (ASCB) organize educational programs within their annual research meetings. It is also highly recommended that departments occasionally hire Ph.D. level biologists with interest or specialty in biology education to enrich the department. This is one area in which the age of this document is beginning to show. The University of Delaware not only has hired instructors and biologist with education interests; it has a long history of maintaining an office for the development of faculty teaching. Previously known as the Center for Teaching Effectiveness (CTE), the current Center for Teaching and Assessment of Learning has served as an internal source for advancing most of the recommendations of techniques and assessments for student centered learning since 1975 (University of Delaware, 2018a).

The office has also linked with a national body for the education research to fan the flames of change and develop future faculty by joining Center for the Integration of Research, Teaching and Learning (CIRTL) which promotes all participants to drive research in education in their particular field using Teaching as Research (TAR) projects (University of Delaware, 2018b). While the University of Delaware may be a great model for offering these resources, it shows the importance of buy in to the concept by all stakeholders, which include faculty, students, administration, funding bodies, and professional societies as well as the need for implementation by the faculty. Thus it is a necessary question to ask the faculty if they have utilized the resources in CTAL or any other similar educational advancement resources as well as if they find the resources and effort useful.

Summary

In summary, the *Vision and Change* document continues to emphasize main topics laid out by the previous AAAS and Biology Education documents published since 1990. Both the *Science for all Americans* and *Bio2010* documents argued that the amount of material taught in courses need to be cut and instructors should go into greater depth. It has also been known for a long time that lecture is not the best method for teaching, yet there seems to still be a great deal of it in the modern American university. Learning needs to be active, and the students must be engaged and interacting with the instructor as well as the material. Diversity in the classroom and beyond is essential for the advancement of science, problems will always rise up and it would be best to have many different minds thinking of the solutions.

It has been argued since 1989 that students should be doing authentic research and faculty must exemplify the passion and spirit of science. It seems *Vision and Change* differs from the other documents in that it offers direct examples that are replicable and direct action items that can be enforced and carried out in ones own department. AAAS has also done a better job this time at calling out the stakeholders and showing the importance of an active role in leadership and academic as well as professional societies for the development of instructors willing to utilize student centered learning techniques that have been backed by recent educational research.

References

Allchin, D. (2013). Problem- and case- based learning in science: An introduction to distinctions, values and outcomes. *CBE-Life Sciences Education, 12,* 364-372.

Beck, C., Butler, A., Burke da Silva, K. (2014). Promoting inquiry based teaching in laboratory courses: Are we meeting the grade? *CBE-Life Sciences Education, 13*, 444-452.

Brewer, C. & Smith, D. (2011). *Vision and change in undergraduate biology education* (1st ed.). Washington, D.C.: American Association for the Advancement of Science.

Brownell, S. E., Hekmat-Scafe, D. S., Singla, V., Chandler Seawell, P., Conklin Imam, J. F., Eddy, S. L., Stearns, T., Cyert, M. S. (2015). A high enrollment course-based undergraduate research experience improves student conceptions of scientific thinking and ability to interpret data. *CBE-Life Sciences Education. 14,* 1-14.

Brownell, S. E., Price, J. V., Steinman, L. (2013). A writing-intensive course improves biology undergraduates' perceptions and confidence of their abilities to read scientific literature and communicate science. *Advances in Physiology Education, 37* (1), 70-79.

Bonney, K. M. (2015). Case study teaching method improves student performance and perception of learning gains. *J. Microbiol. Biol. Educ., 16* (1), 21-28.

Connell, G. L., Donovan, D. A. Chambers, T.G., (2016). Increasing the use of student centered pedagogies from moderate to high improves student learning and attitudes about biology. *CBE-Life Science Education, 15*, 1-15.

D'Souza, M. J., & Wang, Q. (2012). Inter-institutional partnerships propel a successful collaborative undergraduate degree program in chemistry. *Journal of College Teaching and Learning. 9* (1), 245-252.

Ebert-May, D., Derting, T. L., Henkel, T. P., Middlemis Maher, J., Momsen, J. L., Arnold, B.,

Passmore, H. A. (2015). Breaking the cycle: Future faculty begin teaching with learner-centered strategies after professional development. *CBE-Life Sciences Education, 14*, 1-12.

Findley-Van Nostrand, D., Pollenz, R.S. (2017) Evaluating psychosocial mechanisms underlying STEM persistence in undergraduates: Evidence of impact from a six-day pre-college engagement STEM academy program. *CBE Life Science Education*.

Hourihan, M., Parkes, D. (2016). *Guide to the president's budget: Research and development FY 2017.* AAAS. Retreived from http://www.aaas.org/rd-budget-and-policy-program.

Hourihan, M. (2015). Federal budget trends: A short summary. *Federal R&D budget overview.* AAAS. Retrieved from http://www.aaas.org/rd-budget-and-policy-program.

Jensen, J. L., Kummer, T. A., Godoy, D. d. M. (2014). Improvements from a flipped classroom may simply be the fruits of active learning. *CBE-Life Sciences Education, 14* (1), 1-12.

Knight, J. K. & Wood, W. B. (2005). Teaching more by Lecturing Less. *Cell Biology Education*, *4* (4), 298-310.

Lee, S. W. & Tsai, C. (2013). Technology-supported Learning in secondary and undergraduate biological education: Observations from literature review. *Journal of Sceince Education and Technology, 22* (2), 226-233.

Linn, M. C., & Eylon, B. S. (2011). *Science learning and instruction: taking advantage of technology to promote knowledge integration.* Routledge.

Liu, O. L., Rios, J. A., Heilman, M., Gerard, L., Linn, M.C. (2016). Validation of automated scoring of science assessments. *Journal of Research in Science Teaching. 53* (2), 215-233.

Luckie,D.B., Aubry, J. R., Marengo, B. J., Rivkin, A. M., Foos, L. A., Maleszewski, J. J. (2012). Less teaching , more learning: 10-yr study supports increasing student learning through less coverage and more inquiry. *Adv. Physiol. Educ. 36*. 325-35.

Manduca C. A., Iverson E., Mcconnell D. A., Bruckner M., Greenseid L., Macdonald R. H., Tewksbury B., Mogk D. W. (2014). *On the cutting edge: combining workshops and on-line resources to improve geo-science teaching.* Paper presented at the Geological Society of America Annual Meeting, held 19–22 October 2014 in Vancouver, BC.

National Research Council. (2003). *BIO2010: Transforming Undergraduate Education for Future Research Biologists.* National Academies Press.

Nauen, J., Kasprzak, M. (2017). *BISC207 Introductory Biology 1 for sections not integrated with chemistry: Laboratory manual.* Hayden McNeil.

O'Donnell, K., Botelho, J., Brown, J., Gonzalez, G. M. (2015). Undergraduate research and its impact on student success for underrepresented students. *New Directions for Higher Education. 169*, 27-38.

O'Rourke, M., Crowley, S., Eigenbrode, S. D., Wulfhurst, J. D. (2014). *Enhancing Communication & Collaboration in Interdisciplinary Research.* Sage: Los Angeles.

Pelaez, N.J., Boyd, D.D., Rojas, J.B., Hoover, M.A., (2005). Prevalence of blood circulation misconception samong prospective elementary teachers. *Advances in Physiology Education 29*. 172-181.

Rohe, B.G. (2015). *BISC833 Biology Curricula Review*. Newark, DE.

Ruiz-Alfonso, Z. & Leon, J. (2016). The role of passion in education: A systematic review. *Educational Research Review, 19*, 173-188.

Rutherford, F.J. (1990). *Science for All Americans*. New York: Oxford University Press.

Shortlidge, E. E., Bangera, G., Brownell, S. (2016). Faculty perspectives on teaching course-based undergraduate research experiences. *BioScience, 66* (1). 54-62.

Spell, R. M., Guinan, J. A., Miller, K. R., Beck, C. W. (2014). Redefining authentic research experiences in introductory biology laboratories and barriers to their implementation. *CBE-Life Science Education. 13*, 102-110.

Stanger-Hall, K. F. (2012). Multiple-choice exams: An obstacle for higher-level thinking in introductory science classes. *CBE-Life Sciences Education. 11* (3), 294-306.

Teasdale R., Budd D., Cervato C., Iverson E., Kraft K. J., Manduca C., McConnell D. A., McDaris J. R., Murray D. P., Slattery W. (2011). *Enhancing student-centered teaching practices: approaches developed on the new Cutting Edge Geosciences RTOP website.* Paper presented at the Geological Society of America Annual Meeting, held 9–12 October 2011, in Minneapolis, MN.

Thiry, H., Weston, T. J., Laursen, S. L., Hunter, A. B. (2012). The benefit of multi-year research experiences: Differences in novice and experienced students' reported gains from undergraduate research. *CBE-Life Sciences Education. 11* (3), 260-272.

University of Delaware. (2018a). *Problem based learning at UD.* Retrieved from http://www1.udel.edu/inst/partners/index.html .

University of Delaware. (2018b). *UD's CIRTL Network Membership.* Retrieved from http://grad.udel.edu/cirtl/ .

University of Delaware. (2017). *Undergraduate Programs: Department of Biological Sciences*. Retrieved from http://www.bio.udel.edu/undergraduate-programs .

Appendix D

DEPARTMENT OF BIOLOGICAL SCIENCES STRATEGIC GOALS ALIGNMENT WITH AAAS NATIONALLY RECOMMENDED STANDARDS

Introduction

Purpose

The purpose of this research is to investigate the strength of alignment of the strategic goals of the University of Delaware Department of Biological Sciences with the current trends in biology as well as how they all align with the *Vision and Change* document released from joint effort of many of the funding and influential federal bodies in the life sciences.

Justification

The University of Delaware Department of Biological Sciences, as well as many other university's biology or life science departments, is tasked with a difficult proposition. In the current research-funding environment, many faculty are losing grants and the undergraduate demand for careers in academia and industrial research is waning (Holm, Carter & Woodin, 2011). The department is now more reliant on teaching courses to sustain departmental funds and recently the University of Delaware biology department has been losing one of it's core student populations, pre-medical degree students, to an internal university source, the College of Health Sciences.

The College of Health Sciences has recently begun to gather steam through the word of the student body, that they are the new path towards a graduate medical degree. The College of Health Sciences has been creating a catalogue of courses that come in direct competition with the Department of Biological Sciences course offerings, as well as having a new found reputation for research funding success and new buildings and infrastructure. Currently the College of Health Sciences is the more attractive option at the University of Delaware for incoming students. The College of Health Sciences is currently expanding into new buildings with a clear plan for developing the college into a first class research and educational institution.

The college is likely pulling students interested in the medical field from the Department of Biological Sciences. According to the College of Health Sciences 2017 to 2021 strategic plan, they college has grown it's undergraduate population by 34% since 2010. It has also increased the number of undergraduate programs to now include an Applied Molecular Biology and Biotechnology program, which could have competed directly with the discontinued Department of Biology B.S. in Biotechnology (University of Delaware, 2017). The College of Health Sciences also has created 7 new graduate degree programs (4 more projected by 2021). The faculty population has increased by 45% and that faculty has accounted for over $82 million of grant funding (University of Delaware 2017). It is with this in mind that I will review and critique the Department of Biological Sciences mission statement and website listed course offerings for it's alignment with the new dogma in undergraduate biology education.

Strategic Goals

The strategic goals or projected learning outcomes of a department are different than the mission statement. A properly constructed mission statement should be short, sweet and to the point. It is a one-sentence directive for all aspects of the department to works towards achieving (Henrickson, 2010). There is much more detailed information in the strategic goals, or strategic plan statements that can be found on university or departmental websites and literature. In most instances these include the who, what, where, and when of passing of knowledge onto the pupil (Cottrell, 2011). Furthermore, the purpose of the education should be stated so the reader and prospective student have an understanding of the opportunities available to them once their education is completed.

The University of Delaware Department of Biological Sciences undergraduate program statement is as follows (University of Delaware Department of Biological Sciences, 2011):

> "The biological sciences curriculum helps students develop an understanding of principles governing biological processes that span a continuum from molecules and cells to organisms and ecosystems. In addition to conveying fundamental scientific knowledge, our curriculum aims:
>
> • To provide opportunities for students to understand and use the process of scientific inquiry
>
> • To promote development of students' critical thinking and problem-solving skills, and
>
> • To help students gain the background essential for making informed decisions about issues that relate to science, technology, and the environment
>
> Majors are educated in the biological sciences by means of formal course work, laboratory and field research projects, volunteer experiences, as teaching assistants in some of the biology laboratory classes, and through individual studies guided by biology professors.

The biological sciences major provides a foundation for advanced study of biology at the graduate level, for further training in such areas as the health professions, environmental science, law, biomedical ethics, genetic counseling, journalism, and public health, and for a wide array of career opportunities."

This strategic plan for student outcomes as well as the message from the department chair (University of Delaware Department of Biological Sciences, 2014) will be compared to the AAAS supplied framework for undergraduate student biology literacy as laid out in the following section.

Theoretical Framework

The document entitled *Vision and Change in Undergraduate Biology Education, A call to Action* is a summary of the findings and discussions from a national conference hosted by the American Association for the Advancement of Science (AAAS) in association with National Science Foundation (NSF), National Institutes of Health (NIH) and the Howard Hughes Medical Institute (Medina, Ortleib & Metoyer, 2014). The NSF, NIH, and HHMI are some of the major funding bodies in biology education as well as for national basic biology research. The AAAS a renowned organization that is responsible for publishing *Science Magazine*, one of the most well regarded journals in the field with the 12th highest impact factor of all biomedical journals. These are organizations that have the power and influence to make changes in biology curricula at a national level, when they speak everyone listens.

The demands on current life science and biology departments listed above, as well as the stigma that most life science courses are taught in a classical (A.K.A. boring) lecture style with an emphasis on rote memorization, required a rethink of how the life sciences should be taught, the learning outcomes associated with them and the key concept any student undertaking the life sciences should come out understanding thoroughly (Mulnix & Vandegrift, 2014). The document itself is over 60 pages long with several chapters and so many thought provoking ideas that it is difficult in the time and space offered here to fully digest it, however many others have boiled the document down into the following key student outcome goals and concepts as noted from this excerpt from an editorial from the National Association of Biology Teachers then President Mark D. Little (2013):

> "It highlights that for a student to be biologically literate, he or she needs to have an understanding of five core concepts. These are (1) Evolution, (2) Structure and Function, (3) Information Flow, (4) Pathways and Transformation of Energy, and (5) Systems. The report calls for these core concepts to be integrated with core competencies and disciplinary practices, including (1) the ability to apply the process of science, (2) the ability to use quantitative reasoning, (3) the ability to use modeling and simulation, (4) the ability to tap into the interdisciplinary nature of science, (5) the ability to communicate and collaborate with other disciplines, and (6) the ability to understand relationships between science and society."

Methodology

Using the University of Delaware strategic goals statement as listed above I determined the inclusion or exclusion of the five core concepts and six competencies listed in the AAAS document. I used the departmental website for purpose of identifying the degrees and concentrations and specializations as well as the core courses offered to determine if the key concepts would have been covered in the core courses. Utilizing the mission statement or opening website statement I determined how the program was described and whether they the publisher infers a career direction. The major concern was if and when the publishers recommend a particular pathway to graduate school, professional schools, medical schools, or employment into the biotechnology workforce.

The final assessment and comparison parameters involved mapping out the core requirements for the B.A. and/or B.S. in Biology from the University of Delaware's requisites and recommended electives. The major focus was on Biology, Chemistry, Physics, and Math requirements for completion of degree. Of special interest were courses that obviously reference the AAAS key concepts required for biology literacy. The data is represented by a table in excel format for quick reference.

Again, the final recommendations reflect the data mined from website statements, major offerings and course requirements for completion. I expect to make recommendations on how the University of Delaware's Department of Biological Sciences can offer/present the majors to students as well as recommended career options or goals. I also recommend changes to the tracks/majors or offer insight into collaborations with other departments for major offerings, as well as to avoid possible conflict with other departments. The finally recommendation is to make changes to the required and recommended curricula for the majors in the Department of Biological Sciences to align them more with the AAAS document *Vision and Change*.

Results

Strategic Goals and Chairs Welcome Statements

When comparing the statements to the recommendations for biology literacy from the AAAS, the University of Delaware Department of Biological Sciences performed admirably. The statements provided in Table D.1 are examples for 5 out of the six key areas of core competencies and disciplinary practices. The requirement for applying the process of science was answered in almost the exact same wording. The requirement for the ability to use quantitative reasoning was less obvious. However, the requirements for tapping into the interdisciplinary nature of science, communication and collaboration, and understanding the relationship of science with society are also well identified in the strategic goals and chair's welcome statements.

Table D.1
Examples of Alignment with the Core Competencies and Practices Outlined by AAAS.

Recommendations from *Vision and Change*	**Items found qualifying from University of Delaware Department of Biological Sciences**
Ability to apply the process of science	To provide opportunities for students to understand and use the process of scientific inquiry
Ability to use quantitative reasoning	To promote development of students' critical thinking and problem-solving skills

Ability to use modeling and simulation	N/A
Ability to tap into the interdisciplinary nature of science	Now and in the future, the world faces great challenges, including issues in healthcare, energy, environmental preservation, and food production
Ability to communicate and collaborate with other disciplines	Collaborations with others on and off campus are valued. Research highlights displayed on these pages are intended to catalyze conversations, encourage involvement, and stimulate the generation of new ideas.
Ability to understand relationships between science and society	To help students gain the background essential for making informed decisions about issues that relate to science, technology, and the environment

Program Degrees, Majors or concentrations/Specializations

Information was pulled from the website between September and November of 2015 to determine if the degree offerings or specializations were any indicators of the learning of key concepts of biology as recommended by the AAAS document *Vision and Change*. The University of Delaware only exemplified two out of five of the recommendations as noted in Table D.2. Structure and function are easily covered by the cellular and molecular specialization while a pathways understanding would be offered by the pharmaceutical specialization.

Table D.2
Examples of Alignment of Degrees with the Key Concepts Outlined by AAAS

Recommendations from *Vision and Change*	**Degrees found qualifying from University of Delaware Department of Biological Sciences**
Evolution	N/A
Structure and Function	B.S. Biology, cell, molecular & genetics
Information Flow	N/A
Pathways and Transformation of Energy	B.S. Biology Pharmaceuticals
Systems	N/A

<u>Requisites and Co-requisites and Electives</u>

Finally, information was pulled from the website to determine if the course offerings or were strong indicators of the learning of key concepts of biology as recommended by the AAAS document *Vision and Change*. The courses required for many of the degrees offered by the University of Delaware satisfy as examples of the recommended required concepts for undergraduate biology literacy. Only Information flow was missing an example in the courses or degrees offered as noted in Table D.3.

Table D.3

Examples of Alignment of Courses with the Key Concepts Outlined by AAAS

Recommendations from *Vision and Change*	**Courses found qualifying from University of Delaware Department of Biological Sciences**
Evolution	Required course for B.S. Biology, cell, molecular & genetics
Structure and Function	Cellular or General Physiology a required or selected course for all degrees
Information Flow	N/A
Pathways and Transformation of Energy	Biochemistry is a required course for 2 of 5 specializations
Systems	Cell Cellular, General Physiology or Ecology is a required or selected course for all degrees

Limitations

Even though the Chair's Welcome and Strategic Goals statements were brief, they still very well fulfilled the recommendations for core competencies and disciplinary practices. It is not known whether the University of Delaware Department of Biological Sciences wrote these statements with the *Vision and Change* call to action in mind, it may have just been coincidental that it contained these key words.

Also, when comparing majors offered to the recommendations for key concepts and practices, it may seem there is little evidence to go on as the University of Delaware offers very few degree concentration or specializations. Also, on the website there is little information offered on the goals of the specific specializations.

However, other institutions offer degrees in evolution, systems biology, and quantitative biology. Simply having these degrees available would satisfy the recommended direction of the department. To note, the University of Delaware does offer a degree in quantitative biology, but it is not listed with the Department of Biological Sciences in an obvious manner. It is a Computer Sciences degree in association with the Department of Biological Sciences. Also, the University once offered a B.S. in Biology concentrating on Biotechnology, yet that was discontinued as of 2014.

Conclusion

The University of Delaware Department of Biological Sciences has done a tremendous job of aligning itself with what will likely become the manifesto for undergraduate biology education. While this system of aligning college or departmental goals with the *Vision and Change* document has been done with success in the past, it should be noted that the author stated the college in question still had some rather strong growing pains (Raimondi, Marsh & Arriola, 2014). It was a lengthy process that was taken on in stages, first they coincidentally updated the goal statements prior to the *Vision and Change* document coming about. It then took committed scheduled change to bring about the actual curriculum change. I have a lingering question as to whether the University of Delaware was as lucky also, but I am also not seeing the structured, directed progress to create new coursework and redesign the goals of each individual class.

Recommendations for the University of Delaware

When it comes to strategic goals and Chairs welcome statements, they only really missed out on offering information on how students would gain the practice of using modeling and simulations to help them become more biology literate. Within the very short statements exposed to prospective students within the first few mouse clicks of the Biology Undergraduate program home page, the department performed admirably. However, the University of Delaware could benefit from better advertising the majors offered towards particular career paths. The department should also consider changing the goal statements to include information about the quantitative requirements for almost all degrees offered in biology. Physics I and II as well as Calculus I are required courses, yet I could see how the advertisement of those courses to early prospective students may be a slight deterrent.

The University of Delaware department of biological sciences should consider aligning itself more completely with the AAAS document as well as other peer institutions and separate the B.A. and B.S. into Cellular & Molecular Biology and Ecology & Evolution to emphasize the key concepts of evolution and systems biology as hallmarks as important as cellular and organismal structure and function. This may be a long-term consideration as requisite coursework and instructional faculty that specializing in evolution would be needed, or research faculty with an interest in the endeavor would need a reconfiguration of workload.

Creation of a bioinformatics or computational biology degree should be considered to assist the department in filling in the gaps in its alignment within modeling and simulation usage and information flow key concepts. It could either be housed in biology or co-owned with computer sciences. Possibly as the program is building biology could be a concentration in the computer science B.A. or B.S. degree. The status of a similar program is difficult to discern from the current university website. There is a Computer Science B.S., but it does not show any concentrations or specializations.

Reflection

Even though the department did a very good job in it's statements and course offerings, I am still not very sure if they are actually advancing into next realm of undergraduate biology literacy. In writing this article, I was left with many thoughts and questions. It's easy to talk a good game but are they actually following through with it? I do not have access to every course offering syllabus and teaching statement for every professor and instructor within the department. I did not have the time to sit in on any class of the classes. But, what I can go by is the word of mouth and interactions I have with my peers in the department. I know of several instructors and professors that have begun using some of the greater recommendations from the course textbook *Curriculum 21*. They have started using new technologies in creative ways. Many have started to utilize the current technology that the students are already adept with. I know of a microbiology instructor that had his students create and load Youtube® videos on various topics. One of the best was a collaborative interdisciplinary video on how mathematics plays into epidemiology and virulence. They used very elegant formulations along with the classically hilarious example of food poisoning, to show just how long it would take for someone to suffer symptoms after *E. coli* ingestion. I also have had my students begin to make multimedia presentations for participation points in my Introductory Biology courses. Yet I feel we are the minority in the department, I don't think the use of these technologies has worked into the fabric of the department. Senior faculty feel it is gimmicky and is not considered during yearly reviews or promotion and tenure talks.

Also, It was noted in the literature that the uptake of the AAAS document was very slow in the beginning. I would like to know just how the University of Delaware compares to other universities, both peers and aspirational institutions. If it were possible, I would do the same analysis of websites, degree and course offerings from other universities in the Mid-Atlantic and Northeast to find where the University of Delaware fits into the grand scheme of things. Possible compare us to some of the more forward thinking institutions such as Princeton and UCDavis It seems, on paper, that we are headed in the right direction. Some of the literature cited here stating the success of implementing the recommended standards was from small colleges with small student to teacher ratios. Leaving us with the final question: Would it be easier to implement many of the creative aspects and hands on simulation work in these close knit communities as opposed to the faceless 240 student classes I have taught in the past?

References

Cottrell, J. R. (2011). What are we doing here, anyway? *College & Research Libraries News, 72*(9), 516-520.

Henrickson, G. (2010). Winning the mission statement arms race. *Change, 42*(6), 33-34.

Holm, B., Carter, V. C., & Woodin, T. (2011). Vision and change in biology undergraduate education: Vision and change from the funding front. *Biochemistry & Molecular Biology Education, 39*(2), 87-90.

Little, M. D. (2013). Embrace vision & change. *American Biology Teacher (University of California Press), 75*(6), 368-368.

Medina, S. R., Ortleib, E., & Metoyer, S. (2014). Life science literacy of an undergraduate population. *American Biology Teacher (University of California Press), 76*(1), 34-41.

Mulnix, Amy B., & Vandegrift, E. V. H,. (2014). A tipping point in STEM education reform. *Journal of College Science Teaching, 43*(3), 14-16.

Raimondi, S. L., Marsh, T. L., & Arriola, P. E. (2014). Integrating vision and change into a biology curriculum at a small comprehensive college. *Journal of College Science Teaching, 43*(5), 33-39.

University of Delaware. (2017c). *Strategic Plan 2017-2021.* Retrieved from http://chs.udel.edu/wp-content/uploads/2017/11/Strategic-Plan-2017-2021.pdf

University of Delaware Department of Biological Sciences. (2011). *Undergraduate programs.* Retrieved March 18, 2016, from http://www.bio.udel.edu/undergraduate-programs

University of Delaware Department of Biological Sciences. (2014). *Welcome from the chair.* Retrieved March 18, 2016, from http://www.bio.udel.edu/welcome-chair

Appendix E

ANALYSIS OF CURRICULAR MAPPING OF BIOLOGY COURSE OFFERINGS TO GENERAL EDUCATION OUTCOME GOALS

Context

In May of 2015, the University of Delaware Faculty Senate approved a change to the objectives of General Education to help students attain competency. According to Chris Knight, the chair of the Faculty Senate Committee on General Education at the University of Delaware, the latest push for change was to allow for greater accountability on behalf of the university to the competencies of it's graduates. Also, the results of the curricular mapping are to create a campus-wide registry that shows in which classes students can attain the expected general education goals. To that end, students will be able to make informed decisions about their course registrations. According to Knight the goal is to have a general education curriculum that compliments rather than runs parallel to students majors (Knight, 2016).

During the following spring semester 2016, the Center for Teaching and Assessment of Learning (CTAL) asked each department within the university to participate in curricular mapping. Curricular mapping is an exercise that visually portrays the departmental curriculum opposed to how well the courses meet the new General Education objectives. The instructions for the General Education Curriculum mapping were laid out in the *Guide: Mapping UD Courses to the General Education Objectives* (2016) manual that was posted to the University of Delaware Department of Biological Sciences intranet along with a labeled blank spreadsheet for completion by the departmental faculty. Faculty were to take into account the General Education goals as laid out by the manual and score how well the courses they taught met the standards. The score is coded as N - NOT APPLICABLE, the faculty has no intention to observe student learning regarding this goal; M - for MINOR, the faculty will observe only some student learning regarding this goal; or S - for SIGNIFICANT, the faculty will observe significant student learning regarding this goal as judged by the faculty after being instructed on the goals and given examples of goals to be noted within their courses. The goal of the mapping is to obtain a rough score card for how the base curriculum meets the university recommended standards.

Though the data was collected by the then Department of Biological Sciences Chair, and analysis will be ongoing from the Faculty Senate Committee on General Education, the following analysis is by the author only with no input from the Faculty Senate Committee on General Education. The author is unaware of the analysis by the committee, the purpose of this analysis is to determine in which courses students are exposed to the recommended skills outcomes, if at all and when the exposure occurs within the course sequence. As a tangible result of this study, the analysis could be returned to the Department of Biological Sciences as a resource for the instructors to determine if changes are needed in the sequence or number of times students are exposed or assessed for these skills. Recommendations from the author will be concluded in the discussion section.

Sample

The general education goals were obtained from the University of Delaware General Education website (http://sites.udel.edu/gened/). The goals were copied verbatim for both successful student characteristics and the educational requirements necessary to create such students. Further defining characteristics of the objectives were determined through the handout that accompanied the CTAL's instructions for curricular mapping as well as the website for the University of Delaware's Resolution on Resolution on General Education Addendum which contains explanatory paragraphs for all the expected student characteristics and outcomes (http://sites.udel.edu/gened/resolution-on-general-education-addendum-explanatory-paragraphs/).

The following is a breakdown of the student learning outcomes as defined by the Center for Teaching and Assessment of Learning General Education Mapping Guide and with possible outlooks or examples of how that would be portrayed by the Department of Biological Sciences faculty. The first objective states that students are to read critically, analyze arguments and information, and engage in constructive ideation. Read critically refers to a student's ability to create meaning through interacting with written documents within the field of study that may pose a different cultural or contemporary value. Essentially, can the student compare the author's values to his or her own?

The second portion of the first objective is to analyze arguments and information, which means to break down large topics into smaller digestible portions which would hopefully lead to better understanding and reflection of the student's own attitudes about science concepts or related issues. Engage in constructive ideation, is simply the students ability to create new concepts from the learned material. What is evident in this language is the progression through Bloom's taxonomy from the bottom levels of understand and analyze through to evaluate and then create. The student offering solutions to previously unsolved problems in biology would exemplify mastery of critical thinking.

The second objective pertains to communication and is written as communicate effectively in writing, orally, and through creative expression. Simply put the first, written, pertains to using text combined with scientific imaging or graphing in the proper format to advance a concept or argue persuasively a hypothesis, experimental design or results. It is also expected that the student be able to validate a suitable reference source. To be able to communicate orally in this context is to speak or present an idea, concept or conclusion to an audience with the intent and skill to advance the knowledge of the audience, or create a new understanding of the material or persuade the audience to reflect on the topic. It is noted in the CTAL's definition that this should also be based on credible evidence and less on opinion.

The third and final aspect of communication recommended by the general education objectives, communicate through creative expression, is one way of stating "other" as an option of communication. If the biology course includes a method of communication other than written and spoken presentation, the instructor can conclude that they complied with the entire second objective. It is noted that an example of this creative communication includes animations and videos that the student has made from inception to delivery. While this recommendation does not step through Bloom's taxonomy such as the first objective of critical thinking had, one can argue that each aspect could be portrayed through the media presented, written, oral or other. A student can express understanding, analysis or synthesis using the tool of the media of choice.

The third objective of the general education student-learning outcome is to have the student work collaboratively and independently within and across a variety of cultural contexts and a spectrum of differences. According to CTAL, this goal is defined as having the student value different cultures and the possible outcomes from collaboration with diverse perspectives. Just as before the language of the objective cues into Bloom's taxonomy as the driving force behind objectives creation.

The final line of the CTAL definition states the student will learn diverse perspectives, assimilate the knowledge and synthesize solutions, which is classic progression through Bloom's taxonomy. The objective is however broken into two aspects of working within the group and then individually. One would imagine though how it would be difficult to assimilate aspects of other cultures when working individually unless the student has already worked within a diverse group. It is possible that the objective is written in this way to suggest a chronological order, however the limitation should be noted when scoring how well an instructors course performs against this objective. It would be important to consider the level of student exposure in the progression of the curriculum.

The fourth objective of critically evaluates the ethical implications of what they say and do is again broken down by the CTAL staff through the framework of Bloom's taxonomy. This general education objective asks if the student is able to recognize an ethical situation, assess their own ethical values and then analyze others ethical positions. The end point here is not necessarily to synthesize ethical values though, but for the student to act ethically or practice ethical decision making after thorough analysis.

The fifth and final objective for student-learning outcomes is to have the student reason quantitatively, computationally, and scientifically. This is in reference to having students use tools to manipulate data sets and base decision-making on the evidence or statistical analysis of the data. This objective doesn't travel through Bloom's taxonomy so much as put a major emphasis on analysis, which would be a skill necessary for future success.

Analysis

The scoring or rating on how well an individual course performed in offering general education objective opportunities for student learning outcomes was N for not applicable, M for minor emphasis, or S for significant or major emphasis. Although all the courses offered in the Biological Sciences catalogue are included in this CTAL study I will only show the results for a subsection of them. Introductory Biology I and II (BISC207& 208 respectively), Cell Biology (BISC305), General Physiology (BISC306), Molecular Biology of the Cell (BISC401) and Genetic and Evolutionary Biology (BISC403) are included for the purpose of representing the "core courses" – those courses that any undergraduate in the life sciences must take or are included in a short list of selected courses that must be chosen from to fulfill a required life science category. Other courses that were analyzed include the available experimental courses listed as Experimental Cell Biology (BISC315), Experimental Physiology (BISC316) and Experimental Molecular Biology (BISC411) as examples of the independent study.

These courses represent the authentic research opportunity courses recommended by the document *BIO2010. BIO2010* is the source from which many recommendations were made in the Department of Biological Sciences 2007 Annual Program Review (APR), and previous artifacts prepared for this ELP (History of Curriculum Change in Biology), which highlighted the importance of independent study for any undergraduate student in the life sciences. They are included in this study as a means of comparison as to how experimental or independent study courses are perceived by faculty to align with the General Education Objectives for Student Learning Outcomes versus the core required lecture based courses. However, to note there are courses listed as Independent Study within the Department of Biological Sciences course catalogue, which for some reason were excluded from the initial study performed by the department chair.

Results

Table 1E shows the initial data analysis of the by the departmental chair in 2016, many of the critical thinking and reading subsections. As Table E.1 shows, the three subsection objectives are scored as being majorly included several times. To note, the required courses of Introductory Biology I & II are the first courses taken in the life sciences majors progression. Therefore according to the instructors, undergraduates are immediately exposed to these skills. BISC401 Molecular Biology of the Cell is the only course to have no alignment with these critical reading and thinking skills as perceived by the instructor. Also of note, is that the subsection goal 1(c) engage in constructive ideation is perceived to be least aligned with biology curriculum. One method to consider the coverage of the general education goals is that the subsection goals of reading critically are minorly included 6 out of 9 opportunities, and significantly included 2 more opportunities and not included 1 out of 9 opportunities.

Analyzing arguments scores second best by being minorly included 7 out of 9 opportunities, and slightly once while engaging in constructive ideation is only included in the curriculum minorly 3 times and significantly once out of 9 opportunities.

Table E.1
Course alignment with critical thinking and reading skills.

Courses	1(a) Read Critically	1(b) Analyze arguments and information	1(c) Engage in constructive ideation
BISC207 Introductory Biology I	M	M	M
BISC208 Introductory Biology II	M	M	M
BISC305 Cell Biology	S	M	
BISC306 General Physiology	M	M	
BISC315 Experimental Cell Biology	S	M	
BISC316 Experimental Physiology	M	M	
BISC401 Molecular Biology of the cell			
BISC403 Genetic & Evolution Biology	M	S	M
BISC411 Experimental Molecular Biology	M	M	S

S= Significant inclusion; M=minor inclusion; blank = not considered included.

Table E.2 illustrates the course alignment with general education communication goals. Though the overarching goal of effective communication is broken into three subsections as the critical thinking and reading goal was, these subsections are noted as aligning less with the biology curriculum as perceived by the instructors.

The subsection goals of effective writing and speaking are included in more opportunities than the third subsection goal of utilizing creative expression which only has one mention of being included. Writing is regularly given more opportunity for inclusion than oral communication. BISC411 Experimental Molecular Biology is the only course to include an instance of creative expression.

Table E.2

Course alignment with general education communication goals.

Courses	2(a) Communicate effectively in writing	2(b) Communicate effectively orally	2(c) Communicate effectively through creative expression
BISC207 Introductory Biology I	M	M	
BISC208 Introductory Biology II	M	M	
BISC305 Cell Biology			
BISC306 General Physiology			
BISC315 Experimental Cell Biology	S		
BISC316 Experimental Physiology	M	M	
BISC401 Molecular Biology of the cell	S		
BISC403 Genetic & Evolution Biology			
BISC411 Experimental Molecular Biology	S	M	M

S= Significant inclusion; M=minor inclusion; blank = not considered included.

Table E.3 summarizes the amount of perceived inclusion of working collaboratively and individually across cultures, goals 3a and 3b respectively, and the inclusion of ethical implications in the curriculum.

Table E.3
Course alignment with cultural diversity outcomes and ethical awareness outcomes.

Courses	**3(a) Work collaboratively across a variety of cultural contexts and a spectrum of differences**	**3(b) Work independently across a variety of cultural contexts and a spectrum of differences**	**4 Critically evaluate the ethical implications of what they say and do**
BISC207 Introductory Biology I	M		
BISC208 Introductory Biology II	M		
BISC305 Cell Biology			
BISC306 General Physiology			
BISC315 Experimental Cell Biology	S		
BISC316 Experimental Physiology	M		
BISC401 Molecular Biology of the cell			
BISC403 Genetic & Evolution Biology			M
BISC411 Experimental Molecular Biology	S		M

S= Significant inclusion; M=minor inclusion; blank = not considered included.

It seems working across cultural contexts and a spectrum of differences is only perceived by instructors to occur in the collaborative setting, with no instances being noted in the individual subsection (3b). Inclusion of critically thinking of ethical implications is not perceived to be included in the curriculum until the 400 level courses of Genetic & Evolution Biology and Experimental Molecular Biology.

The final subsections of instructors perceived alignment with reasoning skills is found in Table E.4. Scientific reasoning is scored as being included most often with 7 instances of significant inclusion and 2 instances of minor inclusion out of 9 opportunities.

Table E.4
Course alignment with reasoning skills.

Courses	5(a) Reason quantitatively	5(b) Reason computationally	5(c) Reason scientifically
BISC207 Introductory Biology I	S	M	S
BISC208 Introductory Biology II	S	M	S
BISC305 Cell Biology			M
BISC306 General Physiology	S	S	M
BISC315 Experimental Cell Biology	S	M	S
BISC316 Experimental Physiology	M	S	S
BISC401 Molecular Biology of the cell			S
BISC403 Genetic & Evolution Biology	S	M	S
BISC411 Experimental Molecular Biology	S	M	S

S= Significant inclusion; M=minor inclusion; blank = not considered included.

Quantitative reasoning scored 6 instances of significant inclusion and 1 instance of minor inclusion, while reasoning computational scored the least number of inclusions yet still had 2 significant instances and 5 minor instances.

Discussion

General Education Objectives for Student Learning Outcomes were at least moderately met. However, some seem to be not met at all by the Core Required courses. Those outcomes include, "communicating effectively through creative expression" and "work independently across a variety of cultural contexts and a spectrum of differences". A third objective, "critically evaluate the ethical implications of what they say and do" was just barely included in the core required courses with 1 count of minor inclusion in BISC403 Genetic and Evolutionary Biology. Scoring the best, which correlates with an instructors perception of meeting the General Education Objectives for Student Learning Outcomes, were the three subcategories of reasoning. "Reasoning quantitatively", "Reasoning computationally" and "Reasoning scientifically" scored several Significant or Major inclusion instances within the core requirement courses.

The three subcategories for reading and thinking critically scored mostly minor inclusion. However, they continually scored minor inclusion, which argues that the topic is perceived by the faculty to be fairly important and included multiple times through the curricular career of an undergraduate in the biological or life sciences. Looking more closely at the subcategories, "Read critically" score a handful of significant instances which is followed by "Analyze arguments and information" in second place and the lowest score in the category going to "Engage in constructive ideation". As noted above in the analysis of the objectives, this follows the hierarchy of Bloom's taxonomy which highlights the perception that the faculty spend a majority of their time in these courses on the lower levels of knowledge, understanding and analysis.

Two of the three communication objectives that score well include "Communicate effectively in writing" and "Communicate effectively orally" scored in that orders. This result is most likely due to the introductory lab courses required assignments that include lab reports and essay answers on exams. The inclusion of laboratory courses within the core required courses also likely lead to the result of the "Work collaboratively across a variety of cultural contexts and a spectrum of differences" scoring so much better than its independent counterpart. In most instances the laboratory courses are setup as group work opportunities with lab groups of 2-3 students working on 10 to 12 different exercises collaboratively throughout the semester.

Scores for the three experimental courses were comparable to the required ones. The strongest category for Student Learning Outcomes is the reason section and subcategories, followed by the critical reading and thinking categories, and then the communication categories. It is here where one of the major differences show through, thanks to the BISC411 of Experimental Molecular Biology "Communicate effectively through creative expression" scores it's first instance of minor inclusion, as does "Critically evaluate the ethical implications of what they say and do". Though it is a single instance, it supports the concept proposed by the *BIO2010* document that more can be learned through the inclusion of experimental labs or independent study courses.

In conclusion, it is noted that the skills recommended by General Education outcomes are fairly well met. Importantly, the undergraduates are exposed to these skills early in the sequence of courses. The first 2 introductory courses exposes the undergraduate to most of the skills needed to be a successful member of educated society. However, having an ethical awareness seems to be less included in the curriculum design through these core courses. This analysis also shows that most undergraduates would learn the general education outcome skills by taking the experiential laboratory courses. Recommendations from this study include increasing the effort to include ethical discussions in the curriculum, as well as repeating the exposure to working in diverse cultural situations. These are skills and awareness that could benefit from multiple exposures.

Limitations

The limitations within this study are great. Though some courses such as the Introductory Biology I & II are averages of several faculty survey data, some courses are just one faculty member's opinion. It is also important to note that there is not a complete abandonment of the poorly accounted for General Education Objectives for Student Learning Outcomes. Several of these outcomes have Minor and Significant inclusion instances in many of the graduate level courses. It should also be noted that undergraduates within the biological and life sciences are required to take at least one graduate level course, which means they would likely be exposed to the other objectives in that one course. It is a limitation of the department's study that it focused on select courses that paints such a poor picture on adherence to the General Education Objectives.

References

Center for Teaching Assessment and Learning. Guide:Mapping UD Courses to the General Education Objectives. University of Delaware website https://sites.google.com/a/udel.edu/facultysenate/gened/documents. Accessed July 23, 2017.

General Education. University of Delaware website http://sites.udel.edu/gened/. Accessed January 4, 2017.

Knight, C.A. (2015). Curriculum Mapping Intro video. University of Delaware website https://sites.google.com/a/udel.edu/facultysenate/gened/documents. Accessed November 1, 2017.

Little, M. D. (2013). Embrace vision & change. *American Biology Teacher, 75*(6), 368-368.

Appendix F

COMPARISON OF GENERAL EDUCATION RECOMMENDATIONS AT UNIVERSITY OF DELAWARE TO AAAS RECOMMENDATIONS

Context

The purpose of the analysis for the alignment of University of Delaware General Education goals with the student learning outcomes from AAAS is to determine if faculty are already aligning well with the AAAS goals prior to the faculty interviews that are yet to come. Though it is entirely inferential, there is the case to be made that if faculty are already aligning their course outcomes with the general education outcomes, they may also be coincidentally aligning with the AAAS recommendations. As an example, if a faculty member is expecting that students become critical readers and thinkers as recommended by the university General Education Outcomes, by inherently being a life science course, they are likely aligning their course with the AAAS recommendation of having students become critical thinkers and readers of scientific material. If there is a great overlap of outcomes between General Education goals and AAAS recommendations, there may already be a format and pedagogical design in which AAAS recommendation are being met without even considering or having read the *Vision and Change* document.

The purpose of this study is to determine how well the General Education goals and AAAS recommendations overlap. The results of this study may be returned to the department of Biological Sciences where it may inform the instructors of the courses on possible changes in the curriculum. It is not the author's intent to analyze each courses alignment with the AAAS and General Education goals, but to inform the instructors and undergraduate program committee and possibly prevent doubling efforts on curriculum alignment with General Education and AAAS recommendations.

Sample

The general education goals were obtained from the University of Delaware General Education website (http://sites.udel.edu/gened/). The goals were copied verbatim for both successful student characteristics and the educational requirements necessary to create such students. The AAAS Vision and Change goals were obtained through the often-referenced summary of the documents written by National Association of Biology Teachers President Mark D. Little (2013).

Analysis

The goals for both were aligned on a spreadsheet and the general level of alignment was determined to be High, Moderate, or Low. If alignment was seen as less than low, no alignment was determined and the box was left blank. To quantify the alignment, since many AAAS goals could align with Gen Ed goals a score was generated by summing the values categorized as follows: High-3 points, Moderate-2 points, Low-1 point, No alignment-0 points. In this manner is possible to grade the alignment of the General Education Objectives for Student Learning Outcomes with the AAAS recommendations.

Results

Table F.1 shows the manner in which the goals aligned along with the scale as to which they aligned. It is noted that there are six AAAS goals and five General Education goals for the University of Delaware. The AAAS goal that shows the highest score(data not shown) for alignment was a tie at 6 points between "The ability to communicate and collaborate with other disciplines" and "The ability to understand relationships between science and society".

Table F.1
AAAS goals alignment with General Education goals.

	AAAS Goals					
	The ability to apply the process of science	The ability to use quanti-tative reasoning	The ability to use modeling and simulation	The ability to tap into the interdisciplinary nature of science	The ability to communicate and collaborate with other disciplines	The ability to under-stand relation-ships between science and society
General Education Goals						
Read critically, analyze arguments and information, and engage in constructive ideation		High				
Communicate effectively in writing, orally, and through creative expression.					High	
Work collaboratively and independently within and across a variety of cultural contexts and a spectrum of differences				High	High	Low
Critically evaluate the ethical implications of what they say and do	Low					Moderate

Reason quantitatively, computationally and scientifically	Moderate	High	High

The AAAS goals that scored the lowest for alignment were "The ability to apply the process of science" and "The ability to understand the relationship between science and society". To note "The ability to use modeling and simulation" scored a similar 3 points, however the previous two recommendations were the only to not score a High value for alignment with any of the General Education Objectives. There was no AAAS goal that did not align at all.

Discussion

As noted in the results section, the goals are written for different audiences therefore the language is not an exact match. However, it was very easy to see how the two AAAS goals "The ability to communicate and collaborate with other disciplines" and "The ability to understand relationships between science and society" matched so well with the General Education goal of "Work collaboratively and independently within and across a variety of cultural contexts and a spectrum of differences". Not only is the language of the goals similar, but also the meanings are practically identical. In either instance it is of utmost importance that a graduate of the University of Delaware and a graduate of any Biological Sciences major, should be able to communicate and collaborate across disciplines and cultural differences. This requires a touch of empathy and understanding, both the cultural viewpoint and desired outcomes of the research and study of different fields. It would be necessary for successful graduates to bridge those gaps to synergistically reach a goal. Proper communication is also necessary to ensure minimum of misunderstanding, whether it be with a colleague from another discipline or a member of the general population.

The AAAS goal that scored lowest was "The ability to apply the process of science", likely scored low because of the definitiveness and specificity of the goal. While it would be a definitive and essential skill to have as a biologist or scientist, the General Education goals are written with a broader pen. At this point in this analysis it is left down to the difference in language and audience for this AAAS goal. The AAAS "The ability to understand relationships between science and society", falls with a low alignment after closer reading of the intent of that goal. It is not overtly stated in the document but hinted that the biology graduate has a responsibility to express the concepts of biology to the general public for the best of all parties included. This hints at beneficence for the common good, or for the greatest number of people.

However, nowhere in the document does the argument of personal ethics come up. This is an area that should be included in all science education; there are myriad topics to be covered under ethics, including plagiarism, harm to study subjects be they human or nonhuman, privacy and confidentiality, as well as concerns for the general population and abuses of human rights in the name of science exemplified by the Tuskegee trials and human subject experiments carried out in Jewish concentration camps. It is noted that this is considered to be the greatest omission from the AAAS goals as well as the General Education Student Learning Outcomes. However, let it be known that gauging an individual's understanding of ethics and alignment of their own personal ethical values is a very difficult outcome to assess. Many questions arise when one begins to attempt to assess ethics, of course diverse cultural norms come into consideration as well as gender and socio-economic standing. It would be a difficult task to assess for a social scientist, much harder even for a biologist.

Of important note, there is a limitation to this study. It is a smaller analysis of only half the original study General Education Objectives. The original study included the four characteristics to have been incorporated into a graduate of the University of Delaware Undergraduate Program. These characteristics include being an engaged citizen, being aware of intellectual strengths and ethical values and commitments, being capable of interpreting the arts and culture of past and present societies, and to have the skills necessary to thrive in a changing world. When these were included in the full previous study, the scores changed and the ranking of alignment changed. However what is noticeable from the complete data table in the raw data, is with the exception of the alignment to the AAAS goal of "The ability to understand relationships between science and society", the alignment of the top portion of the table which involves these characteristics is much poorer than the lower portion of the table that includes the Student Learning Objectives.

Exclusion of the "Characteristic" criteria of the General Education goals, was for multiple reasons. As a means of comparison between the first study above and this current study, it was necessary to only use the objectives that outlined in the departmental chairs survey of faculty. It was also necessary as the language of the characteristics is vague and difficult to assess. Characteristics are difficult to grade. They are not necessarily based on a hierarchical framework such as Bloom's Taxonomy. Also, those doing the assessment would not be trained professionals. The University of Delaware is made up of faculty. Faculty is tasked with the challenge of teaching and assessment of learning. Many learn the ropes through experience or trial and error. Others may be trained in pedagogy and assessment either from graduate school or professional development. None however are professionally trained to assess character. This is out of the realm for faculty to assess so the characteristics must be out of the realm of the curriculum. With this in mind, it may be that the ethical concerns are met within some of the Core Required Courses, but are not recognized within these two studies because it was excluded from the department chair's curricular mapping as well as being a difficult character to assess.

In the larger picture, though it has been beneficial to compare the Department of Biological Sciences faculties perception on the coverage of the General Education Student Learning Objectives through curricular mapping and the alignment of these General Education Student Learning Objectives with that of the AAAS National recommendations for biology and life science graduates. It is now necessary to determine the faculty's perception of how well the curriculum throughout the core-required courses aligns with the AAAS national recommendations. This will be the focus of the final artifact within this ELP document. The alignment will be determined through informed directed interview and focus group discussions. The discussions will be informed by the previous Annual Program Reviews (APRs), the General Education Student Learning Objectives, the AAAS national recommendations and the Curriculum Mapping study.

References

Center for Teaching Assessment and Learning. Guide:Mapping UD Courses to the General Education Objectives. University of Delaware website https://sites.google.com/a/udel.edu/facultysenate/gened/documents. Accessed July 23, 2017.

General Education. University of Delaware website http://sites.udel.edu/gened/. Accessed January 4, 2017.

Knight, C.A. (2015). Curriculum Mapping Intro video. University of Delaware website https://sites.google.com/a/udel.edu/facultysenate/gened/documents. Accessed November 1, 2017.

Little, M. D. (2013). Embrace vision & change. *American Biology Teacher, 75*(6), 368-368.

Appendix G

FACULTY PERCEPTION OF UNIVERSITY OF DELAWARE DEPARTMENT OF BIOLOGICAL SCIENCES ALIGNMENT AND DELIVERY OF CURRICULUM AND PEDAGOGY

Context

The University of Delaware Department of Biological Sciences had its last academic review in 2012. In that academic program review, the authors cited the recommendations within 2011 AAAS document *Vision and Change* as the standards to measure up to for curriculum and pedagogy in the life sciences undergraduate program. Previous work by this author has used public websites as well as peer and aspirational institutions to rate the performance of the University of Delaware Department of Biological Sciences in its alignment with the proposed AAAS recommendations. The department faculty have also previously mapped the undergraduate curriculum against the general education goals from the University of Delaware. And those general education goals have been compared for overlap with the AAAS goals. This study aims to find, directly from the faculty teaching core required courses for biology majors, how the curriculum and pedagogy align with the above AAAS and General Education goals, as well as find input on how the department could benefit or successfully implement curriculum change, and any supports the faculty to use to enact change that lead to successful student learning outcomes.

The following questions were used in interviews with University of Delaware Department of Biological Sciences faculty is to gain the faculty’s perceptions regarding the courses they teach in the program. The interviews were conducted during the spring semester of 2018, with faculty that had taught the courses considered to be "Core Required Courses" from the BISC833 Biology Curricula Review within the past 5 years, the span of time since the last program review. Faculty were invited to interview through email notification in early spring 2018 semester. Participation was voluntary and informed consent was obtained by signed consent form, as well as signed permission for voice recording. Sample size was expected to be between 10 to 12 faculty considering availability. Total participation was 7. The interview process included handouts from the author that highlighted the AAAS *Vision and Change* recommendations for student outcomes in content and skills as well as the recommendations from University of Delaware General Education student outcomes for skills.

Responses were transcribed and coded for analysis. Analysis of the interviews was carried out over the end of the spring semester of 2018 and a list of results and recommendations was created. The recommendations will inform the department on how to better implement curricular change and improve alignment with the American Association for the Advancement of Science recommendations for student outcomes.

Table G.1 shows the question inventory in chronological order throughout the interviews. There are three major topic areas including, Theme 1: Core Curriculum, Theme 2: APR and Curriculum Change, Theme 3: Supports for Advancing Teacher Pedagogy for Student Learning Outcome Success. Questions within the core curriculum theme determine if faculty perceive their course as a core required class and if there are any extraneous or missing courses. The second theme include questions that gauge the faculty perception of how their individual courses align with the recommendations from

AAAS and the University of Delaware General Education Goals as well if the faculty have a history of embracing, opposing or surviving any curriculum change in their career. The third theme asks faculty what instructional development they have undergone and whether it was supported by the University of Delaware, the Department of Biological Sciences, or an outside institution.

Table G.1
Question inventory for faculty interviews with artifact of origination and purpose.

Artifact	Question	Purpose
BISC833 Macro-Curricular Review	Do you consider your course to be part the "Core Curriculum"?	Validation of inclusion of the course.
	Currently there are --- required core courses (list them). Do you agree that these should continue to be included in the required core or not? Why do you think so?	Opinion, future consideration.
	Do you think this department is lacking in core courses?	Extension of BISC833 analysis
	-If so, to what are you making this comparison? Other Institutions? Literature? Etc.	
Vision and Change Analysis	Who do you think is most affected by a curriculum change? (keep probing) Who do you think should be consulted in the event that changes are done? Who else?	Gauge faculty opinion/knowledge and strength of advertising efforts APR/strategic plans
	What knowledge do you have of the most recent University of Delaware Department of Biological Sciences APR and the documents used within?	
	What are you currently doing with your	

	course to ensure that it includes nationally recommended content and skills? Is what your doing adequate? What resources do you need and have used to make changes? What resources do you need and wish to have available to support these changes? (probe) What tangible changes to the core curriculum, if any, have you seen in the last few years? -What do you think of these changes?	 Strength of effort implementation of curriculum change
Vision and Change Comparison	Starting with content recommended by AAAS *Vision and Change*, how well would you say your core required class covers the concepts? When it comes to student learning, what type of assessments do you use? -Have you experimented with other forms of assessment? -If yes, what types? Which ones have you found to be most useful indicators of student learning? -If no, why not? -Has your assessment type been influenced by recent curriculum change? How well do you believe your core required course equips the students with the recommended skills attained by undergraduates? If you believe your course equips students with skills outcomes, do you formally assess skills attainment? What assessment do you use, practical, exams, recorded	Main Focus of content presentation

	observation?	
Vision and Change Comparison & BISC833 Macro-Curricular Review	Which courses in the core curriculum are best suited to assess skill attainment? -Why these selected courses specifically. -If they mention their course follow-up and ask how, if they don't mention it ask why they did not.	Gauge faculty opinion/knowledge of placement of content and skills within the course offerings
General Education Comparison and Faculty Survey	Are you familiar with the most recent change to General Education Outcomes? Do the Gen Ed outcomes affect how you plan or teach your courses?	Gauge faculty opinion/knowledge and strength of advertising efforts of Gen Ed Committee
	Did you participate in the faculty survey involving the map analysis? -If so, how did you score the alignment of your class? -If not, how would you rate your course alignment with the general education goals?	
Gen Ed Comparison	Do you feel the Gen Ed goals and Vision and Change goals overlap? In what ways?	Determine if efforts are being doubled or if there are specific areas of AAAS goals to focus on that are not covered by Gen Ed.
	Do you feel there is a priority for either Gen Ed goals or AAAS goals? If so, which has higher priority? Please provide a rational/explanation.	
Vision and Change Analysis	Are you aware of any administrative assistance for faculty instructional development?	Determine amount of effort from administrative stakeholders
	Have you utilized any administrative assistance?	Determine implementation of

	CTE, CTAL, CIRTL? If so, was it budgeted, supported supplemented, recommended by administration?	administrative effort
	How productive was that experience for you? To what extent were you satisfied? What was most useful in terms of effecting changes in the course or in your teaching? At what level? What was least useful? (probe answers) Were you trained in instruction prior to coming to the University of Delaware?	Determine perceived effectiveness of administrative effort.
	Since joining UD, have you attended a conference/workshop to improve your instruction?	Determine effort of administrative/societal input.
	Have you used materials/concepts gained from these experiences in your instruction? -If yes, what did they use? -If no, why not?	
Demographics	Which courses have you taught? How many years have you taught? Have you been part of preparing an APR?	Demographics
	Have you experienced curriculum change before? What was the scale of the change? How did it affect your instruction? What were some of the pros and cons for that change?	Gauge faculty experience, ease of acceptance of change.

Questions contained in the third theme also ask for faculty recommendations to further administrative support for instructional development. The fourth section is not a theme but a demographics question set that were used create diametric groups and determine if there were different perceptions based on career length, experience or training.

Analysis

The scoring or rating on the survey as to how well an individual course performed in offering AAAS *Vision and Change* recommendations for student outcomes in content and skills was M for minor emphasis, or S for significant or major emphasis. In the instance that a content topic or skill is not offered by the course, the region is left blank. Introductory Biology I and II (BISC207& 208 respectively), Cell Biology (BISC305), General Physiology (BISC306), Molecular Biology of the Cell (BISC401) and Genetic and Evolutionary Biology (BISC403) are included for the purpose of representing the "core courses" – those courses that any undergraduate in the life sciences must take or are included in a short list of selected courses that must be chosen from to fulfill a required life science category.

The quantitative data of the survey was then compared to the qualitative data from the interview to view a larger picture of the situation. In the three topic areas of the interview: curriculum change, general education goals, and AAAS recommendations, statements are analyzed to confirm, refute or enrich the quantitative survey data. When possible demographic data was used to determine if different categories of instructor of record held different perceptions of the three topic areas.

Results

Faculty recruitment was performed utilizing the inclusion determined to be those that have taught the following courses, BISC207, BISC208, BISC305, BISC306

BISC401 and/or BISC403 within the past 5 academic years, 2013 to 2018. University of Delaware course catalogues were used to determine instructor of record for the above classes in the time frame. It was determined that 20 faculty met the requirements to be included in the invitation to interview. The faculty emails were retrieved from the University of Delaware Department of Biological Sciences faculty directory, or associated departmental directories. The recruitment email (Attachment 5, Faculty Recruitment Email) was sent to the @udel.edu email on file with the university on March 14, 2018. Over the next two weeks there were 12 respondents to the recruitment email. Of those 12 respondents 6 were confirmed to participate, 3 declined and 3 expressed an interest but could not participate before the deadline for completion due to scheduling hardship, but offered to participate if strongly needed after the scheduled interview window.

Faculty interviews were conducted over the period of about 2 weeks, from March 19, to March 27, 2018. During that time 6 interviews transpired. The meetings took place most often in faculty offices and meeting rooms. Most faculty agreed to voice recording the meetings. The first 4 meetings were voice recorded as well as real time transcribed to notes, the voice recordings served to verify the note taking. After the 4th interview, the notes were transcribed into electronic format and reviewed for accuracy against the voice recording. It was determined the voice recording could be optional as note taking was accurate. The last two interviews were only manually noted, and then electronically transcribed within 48 hours of the interview.

Surveys were completed at the end each interview and compiled into one electronic document tallying the results on two tables for content and skills respectively.

It was at this point realized that there were no respondents for the core-required course BISC305, or Cell Biology. Further contact to one of the 3 initially hesitant responders produced the opportunity for an interview that included insight into the content and skills perceived to be conferred upon students in the BISC305 Cell Biology class, making it possible to have at least one interview representing all courses. This interview was carried out as described above and the results were added to the compiled interview and survey results for analysis.

The answer to the first set of questions regarding core curriculum had fairly consistent answers. All interviewed instructors considered their course to be part of the core-required curriculum, some enthusiastically “I almost feel like it should be compulsory”. Faculty also had similar positive comments of the other courses considered required, as they all agreed the courses listed should be considered required. When asked if any courses were missing from the list there were three major exclusions, Microbiology, Ecology and Developmental biology were all noted as being absent form the core list twice each. Those responders that had no input stated it was their newness to the faculty and/or lack of knowledge of program requirements that prevented them from making statements on the topic. Evolution was also discussed as to how it was represented in the core curriculum, one respondent noted it was not there often enough, while another stated it was repeated in introductory and within the higher level courses. The means for comparison, when given, were previous employment and education institutions as well as previous experience within the University of Delaware.

The second theme of the interview was curriculum change and the Academic Program Review (APR). When asked who would be most affected by curriculum change, the sentiment was that faculty would be most greatly affected. Only two populations were offered as answers with the second being students. In 4 instances the respondent included both faculty and students. Students alone was replied once and faculty alone was answered twice. Qualitatively, the concern for the effect on students was often whether the outcomes were beneficial for student learning “we want any change to be positive”, “the goal is to improve student outcomes”. When respondents replied that faculty would be those greatest affected by change the concern was for those that have been teaching the course for some time and would have to put in the time and effort to change the direction and instruction of the course. As one respondent put it “If its’ done half-[hearted] then probably the biggest impact is on the faculty that do a lot of work and nothing comes out of it. If there’s no change for the students, then the faculty suffer the most”. Another claims “if there's a major curriculum change then often professors will end up teaching something they are less familiar with; it takes a couple of times teaching a course to really understand what students grasp, what they have a difficult time with. So I think a lot of the burden falls on the teachers”.

When asked who should be consulted in the planning of curriculum change, the most common answer again was faculty, specifically those teaching the courses to be affected. To a lesser extent it was offered that the undergraduate programs committee be conferred or as well as internal teaching assistance fellows, such as the center for Teaching Assessment and Learning (CTAL) who could hopefully provide evidence for the positive outcomes due to the proposed change. In a few instances, research faculty was recommended to be included as source of professional advice as well as instructors of courses that occur downstream of the curriculum change, possibly higher level course instructors or those outside of the department on which their programs rely on the course in question. And only once was it recommended that you speak to students that have completed the course. Countering that one inclusion is a statement that decisively excludes students from the discussion, “because I don’t think it makes all that much difference in the students... As an undergrad, as long as we are doing the best we [the faculty] can”.

Two respondents specifically remembered any curriculum change at the University of Delaware Department of Biological Sciences and they had split responses to the change. One faculty member argued that the introduction of the integrated biology and chemistry courses was “trying to solve a problem that didn’t exist. Sure the integration is supposed to incorporate biology with chemistry but the Biochemistry class solves that problem”. It was not entirely a poor reflection on the change though as it was stated “There were good ideas about decreasing class sizes and active learning, but I think there is some confusion about what component is working to help the student outcomes because there are too many variables as to effectiveness”. Other faculty when asked about possible future resources reflected upon on class size again and will be discussed later.

The only other response to curriculum change at the University of Delaware was a rather positive one that occurred during the transition of the Bachelor of Arts (B.A.) degree requirements. Prior to the change the B.A. degree required nearly as many biology courses as the B.S. in Biology. This left less opportunity for electives. The change was to lessen the number of required biology courses and open the flexibility of the other courses. The interviewee responded that the change was good as the B.A. should have been a more flexible degree offering from the beginning. The faculty stated that while it was a departmental change it did not affect their instruction methods or course design, even though now the courses they taught could have a more diverse student population.

When asked more specifically about the last Academic Program Review that strategized the 2012 curriculum goals, plans, and documents used, less generally about the prospective curriculum change, none of the respondents had knowledge of the APR. Five of the seven respondents stated they were not employed at the University of Delaware during the last APR and two stated that it was so long ago they had no recollection. Therefore none of the respondents had knowledge or recollection that the APR included the goals from the AAAS *Vision and Change* document though one respondent knew of the document by being involved in curriculum change in at the previous employer/ education institution. That single respondent was then again the only one that coincidentally, not by means of policy through the Department of Biological Sciences, referenced the AAAS recommendations during course design and implementation. It was noted that the interviewee expressed interest in discussing the use of national recommendations or standards with other faculty in the design of current and future courses.

Table G.2 shows the compiled results of the 7 interviews for content knowledge as recommended by the AAAS *Vision and Change* document (2011). The first pattern that arises is the one showing that most of the faculty that responded instructed BISC207 and BISC208. In total 3 faculty members that responded solely taught BISC207 & BISC208, or instructed those courses along with one other under consideration for the survey.

Table G.2

Survey results aligning course with AAAS content recommendations completed by faculty

Courses	Evolution	Structure & Function	Information Flow	Pathways and Transform-ation of Energy	Systems
BISC207 Introductory Biology I	M	SMM	SSS	MSS	MS
BISC208 Introductory Biology II	SSM	SMM	S	S	SSM
BISC305 Cell Biology		S	S	S	M
BISC306 General Physiology	M	S	M	M	S
BISC401 Molecular Biology of the cell	M	M	S	M	M
BISC403 Genetic & Evolution Biology	MM	M	SS	M	M

S= significant component; M=moderate component

The number of responses for BISC207 and BISC208 reflect greater population of instructors. Genetic & Evolution Biology, BISC403 had the second greatest number of respondents at 2, while the other courses had 1 respondent each. The second pattern arising from the BISC207 and BISC208 shows greater coverage of Information Flow and Pathways and Transformation of Energy in BISC207, while BISC 208 shows greater coverage of evolution and systems. The courses in which faculty perceive to cover the least recommended content are BISC401 and BISC403. In both of those classes only information flow is covered with significance, while the other four content topics are covered to only a minor level. The only instance of no scoring of a content area in a course was evolution in the BISC305 Cell Biology course. Interestingly, three other topics, Structure & Function, Information flow, and Pathways & Transformation of Energy, were determined to be covered in significant detail according to the instructor.

Analysis of the data in alternate forms shows that throughout the core-required courses, the greatest content coverage as determined by faculty perception is information flow. Throughout the interviews, most faculty (6 out of 7) responded with the central dogma, DNA to RNA to Protein, as the greatest example of information flow. This again is across the core classes from the introductory 200 level courses, 305 and both 400 level courses. Structure & function, Pathways & transformation of energy and systems all scored relatively the same with 4 significant inclusions in content area, leaving evolution to be the least covered. In fact it was excluded from content coverage twice in BISC207 and once again in BISC305. The following statements from the interview express similar lack of coverage for evolution in the higher level courses, "We do cover all of those to some extent besides #1, we could talk evolution of cells but we don't in class", "Evolution is not covered a whole lot", "I think evolution gets poor coverage in the other classes, but maybe ok in 208", "As far as evolution, this is something I would like to cover more of but feel that I don't have enough time".

Table G.3. *Faculty survey results*

Courses	Process of Science	Quantitative Reasoning	Modeling and Simulation	Interdisciplinary Nature of Science	Communicate and Collaborate with other Disciplines	Relate between Science and Society
BISC207 Introductory Biology I	SSM	SSM	MMM	MSS	MSM	S
BISC208 Introductory Biology II	SSM	SSM	MMM	SS	SM	S
BISC305 Cell Biology	S		M	M	S	S
BISC306 General Physiology	S	M	M	M		
BISC401 Molecular Biology of the cell	S			S	M	S
BISC403 Genetic & Evolution Biology	M	SS		S		S

S= significant component; M=moderate component

Table G.3 shows the perceived faculty coverage of the skills recommended by the AAAS *Vision and Change* document. The greatest pattern that emerges is the lack of skills coverage for Understanding the relationship between science and society. With the 7 interviewees teaching several courses, there is the opportunity for 11 responses across all classes. The science and society skill was excluded a majority of the time, 6 out of 11.

However, when it was included, the perception was that the faculty included it in a significant fashion. The skill of using modeling and simulation was included a greater number of times, 8 of 11, yet every time was ranked as being covered only modestly in the course. This is different than the skill of communicating and collaborating with other disciplines that was also included only 8 times, yet had significant inclusion in 3 of those 8 instances. Not surprisingly, the process of science is a skill that is perceived to be covered significantly 7 out of 10 times it was included. Interview responses confirm the lack of coverage of science and society interactions, "The science and society I think we need to emphasize more. The aquatic ecology could be an easy tie in, but I don't think we do very well. It's local water supply and I don't think we tie it in well", "Science and Society, I don't think we do a very good job there. I think it's lost and we don't convey it regularly. We don't talk much about how biology effects us and I don't even think there is a place in the core classes to do it. I think we even undersell the medical aspects of the biology classes", "1-4 very well (process of science, quantitative reasoning, simulation, interdisciplinary nature of science). Not so much for the last 2 (communication and science & society)". Those that do include science's relationship with society express a great interest in conveying the topic to students, "Relationship with science and society, that's a big goal", "Overall the students like these topic discussions [science and society] it's modern and applicable".

In similar fashion, the skill of using models and simulation gets an unenthusiastic response, "We do not talk about models so much", "Modeling and simulation, yes both semesters, we do a lot of concept mapping and a lot of process and system based maps, A leads to B leads to C kind of maps. Not quite as much on the simulation side of things", "We don't do any modeling", "Modeling and simulations, you mean like videos of cell and molecular biology then yes, because it's all models and simulation. It's on such a small scale that it has to be expressed in video and model form. But I don't think it's integrated very well into the lectures".

As noted by the difference between the two tables, the skills are excluded from being considered "covered" more often than the content. There are blank spaces in the skills areas while there are none in the content areas. The blanks refer to regions that the faculty had no coverage in their course. This means all courses incorporate at least some aspect of each content area, there are no blanks. While the faculty perceive to have no coverage of some skills in their courses. Taking into account again each topic could be included 11 times, the total number of times content was excluded is 9 out of a possible 55 times (16%). Skills are excluded from coverage 17 times out of a possible 66 chances (26%). This would seem to infer that content is more important than skills coverage in the core required courses.

Interview answers again confirm the bias of these core classes towards content, most of the courses formally assess for content learning but less so for skills attainment, when asked how well the skills are assessed, some of the following answers were given:

“Yes, but not as much as the content based ones”, “Process of science is assessed in the exams, not simulation or interdisciplinary science, but I ask questions on how genomics may be used. Communicate is assessed in the written questions, and collaborate, its linked to interdisciplinary nature of science.... I hope they understand the science and society, I don’t ask a specific question, no”, “I feel the ability to use quantitative reasoning is tested for using exams. Interdisciplinary, I try to use examples across disciplines. Understanding relationships between science and society, I don’t really test for that but we do talk a lot about ethics”, “Interdisciplinary nature of science is not assessed. I don’t think it’s expected. Communication and collaboration, I have the off semesters do the presentations but overall in the regular semesters the setup is such that the information flow is towards the students. For Science and society there are a few questions on the exam but not many”, “A small percentage of the assessments are ability based”, “The in class exams do assess the first 4 inherently [Process of Science, Quantitative Reasoning, Modeling and Simulation, Interdisciplinary Nature of Science] but not specifically testing for them”.

As for the types of assessments that are used for determining content coverage there is a pattern that arises out of the interviews. It is a relationship between course size and exam type. Initially it seemed to be a pattern of 200 level courses having more short answer and communicative assessments such as poster presentations and group projects, however it should be noted that those aspects are for the sections of BISC207 and BISC208 that have lower enrollment. As noted from an individual that teaches both large and small enrollment BISC207 &BISC208 “Multiple choice exams with the regular spring and fall sessions, but I include written exams in the off season [winter and summer session]. It's class size driven, the regular semesters, the classes are too large, special sessions are small enough for the written exam". That notion is carried through to the large enrollment 400 level courses as well "Because the course is so big, it's 178, there's 3 scantron exams and weekly quizzes". The instructor of another high enrollment 400 level course states their "exams are comprehensive 100 pointers, there are 50 true/false multiple choice questions, and they tell me the multiple choice are harder than the essays".

The general education goals have previously been analyzed for inclusion in the Department of Biological Sciences curriculum. Therefore there was no need for repeating the curriculum mapping, however there were questions about the general education goals as to how the faculty relate to them and/or if they use them for course planning and design. There was a general lack of knowledge about the general education goals, even by the three faculty that had completed the curriculum mapping. They vaguely recollected the event but had no further reflection on the situation and all stated that they do not use the general education goals while designing on implementing there course instruction.

When asked about overlap and prioritization of general education goals and AAAS recommendations, most noted the overlap. Specifically they stated the overlap in the similar quantitative reasoning goals, interdisciplinary nature of science from AAAS and the cultural collaboration goals from general education. Most made connections between the AAAS recommendation that graduates be able to recognize sciences role in society and the general educations goal for ethical thinking. As well as many faculty saw the overlap between the two organizations recommendations to have a critically thinking and communicating student. While 5 of the 7 respondents stated they would prioritize the AAAS *Vision and Change* goals over the general education outcomes, since they are more science focused. There however was one respondents that stated “I hate to say it but I probably like the general education ones better than the AAAS ones”.

The final theme of the interviews involved the role of administrative support for instructional development. The AAAS Vision and Change document’s recommendations on how to support the change of instruction methods in the sciences brought about this aspect of the interview. The AAAS recognize the current situation, that science is mainly a call and respond method of instruction and that the status quo had to change. To that end, there is a general call for departments, universities and institutions to support development of student centered 21st century instruction methods. When asked, most respondents refer to the Center or Teaching and Assessment of Learning (CTAL) as the most visible instructional development office in the university. Those that have used the CTAL find it to be very useful and helpful, as noted “I think our CTAL is phenomenal. Better than previous employer, here CTAL is here for help. That’s there specialty, they are very accessible to everybody I think and I just think its fantastic”. Three faculty interviewees utilized the products of CTAL development, though one argued, “it was productive, but I had to return too many times to say it worked well. The help was a little too general since the help I was getting was from someone that didn’t know the exact content. It was not specific enough”.

Aside from the recommended utilization of CTAL, it was stated that on two occasions the department offered to financially support instructional development by conference attendance. Once for a teaching specific conference and another primary research focused conference. The respondent stated the need for keeping abreast of new developments in their research field was “stimulating and it helps you get re-energized as well as pickup knowledge about things you want to relay to your students”. There was a third instance for financial support for a research conference attendance, but it came from CTAL, reinforcing the role CTAL plays in faculty development.

Aside from those conferences supported by the department and CTAL, most interviewees responded that not much development has occurred outside the University of Delaware. For 6 of the 7 respondents, being a teaching assistant at the previous degree conferring institute was the greatest amount of teaching instruction they had prior to coming to the University of Delaware. Only one respondent stated they had formal training in instruction in the completion of their graduate degree.

When asked if the department should seek out other sources of support there were roughly 3 consensus answers, decrease class sizes, increase the support of instructional development through either support of educational research or release of credit hours of instruction to allow for it, and return to a model of instructional mentoring. The answers that involved large class size were included in limitations to assessment effectiveness (noted previously), willingness to experiment with new methods of assessment and instruction, and decreased student involvement. As one respondent put it “I can see that students can get lost. They should be more proactive but…. I’ve noticed that some of them, if they aren’t doing well immediately in the class, then they can become shy and reserved and have a hard time reaching out. With a large class size it takes time, at least til the middle of the semester to know who the students are”.

Table G.4 *Summary of responses and purpose.*

Theme	Interview Question purpose	Summary of responses
Core-required courses	Validation of inclusion of the course as core curriculum	Course is considered core curriculum. The list of six courses is acceptable but may need to include ecology, behavior, evolution or developmental biology
Academic Program Review and curriculum change	Gauge faculty opinion/knowledge and strength of advertising efforts APR/strategic plans	Students are the main stakeholders in curriculum change. Unless it is done poorly, then faculty has the greatest to lose
		Advisement on change should come from faculty, CTAL, undergraduate program committee/administration
		There was no working knowledge of the results of the latest APR
		Most were unfamiliar with AAAS national recommendations for standards in biological sciences
		One faculty familiar with *Vision and Change* from previous institution implements as much as possible
	Strength of effort implementation of curriculum change	No one was familiar with recent curriculum change either recent hires or no change was implemented
Vision and Change Recommendations	AAAS *Vision and Change* concepts coverage in core required class	Evolution covered well in 207/208
		Structure and function in classes that use cell as model
		Pathways is covered well in 207/208
		Information flow is overall poorly covered

	Systems are covered in physiology and 208(Ecology portion)
Assessments use/recent change to assessment	Instructors in integrated biology (iBC) 207/208 use mixed methods for assessment brought on by DBER Higher-level course generally use multiple choice exams Occasional iClicker usage
Determining if recommended skills are attained by undergraduates in core required courses	Process of science is well covered in all classes Quantitative reasoning is also covered very well in a majority of core required classes Modeling and simulation is not well represented Many interviewed faculty don't feel it is necessary to cover interdisciplinary nature of science Communication is considered to be well covered, but not necessarily with other disciplines Relationship between science and society is only occasionally considered to be covered These skills are assessed in 207/208, but rarely described as being assessed in the higher-level courses Process of science assessed by lab work, communication through lab reports, presentation, written assignments and quantitative reasoning on inherent on exams Modeling and simulation generally not assessed General consensus is that the skills should be

		taught in 207/208 and reinforced throughout the academic career
General Education outcomes	Gauge faculty opinion/knowledge and strength of advertising efforts of Gen Ed Committee	If faculty were around during the summer retreat they were familiar with the change to the General Education outcomes otherwise unfamiliar with the outcomes or vaguely familiar Unanimously, faculty do not take General Education goals into consideration when course design or program planning Critical reading is considered to be a skill taught or used in the core required courses as well as argument and information analysis, however no constructive ideation Effective communication in writing and orally is often used and assessed in iBC and non-integrated 207/208 but less so in higher-level courses. Also class size seems to be an inhibitor to presentations and posters Negative responses and no examples on collaboratively and independently working across cultural context. Generally misunderstood. Two responses for inclusion of ethical implications with examples Quantitative and scientific reasoning is often cited as included in course skills, computational reasoning is often not included

General Education Comparison	Determine if efforts are being doubled or if there are specific areas of AAAS goals to focus on that are not covered by Gen Ed	Most faculty feel the General Education goals overlap with the AAAS goals. They consider the AAAS goals to be more tightly defined and applicable to biology Most would prioritize AAAS over General Education goals One faculty would prioritize General Education goals One faculty argues neither would influence course design and implementation
Supports for advancing teacher pedagogy for student learning outcome success	Determine amount of effort from administrative stakeholders/ Determine implementation of administrative effort/ Determine perceived effectiveness of administrative effort	Overall faculty are aware of some supports of instructional development offered by department/CTAL/Faculty Commons/College (Deans office) Range of responses referring to faculty workshops, summer institutes, off campus conferences and peer review Those that have participated, respond with positive attitudes towards Faculty Commons, CTAL and faculty institutes and found it to be a productive use of time Most frequent response was that seeking out the CTAL or other sources was "recommended" either in person or email but not financially supported or mandatory No faculty responded that the time to visit CTAL or Faculty Commons was budgeted or accounted for in yearly review or tenure and promotion review Outside of the above university

		administrative supports, faculty commented on class size being too large, time should be allotted for program assessment, and that the department should value CIRTL more and educational research as a viable funding mechanism similar to how basic and translational science research is valued
Demographics	Courses/Years teaching/ experience with previous program review or curriculum change	Courses taught include 207/208/305/306/401/403 and various 400, 600, and 800 (graduate) level courses Years teaching ranged from 3 to 28, median was 6 years, average was 11.5 Generally no faculty were involved with the University of Delaware Department of Biological Sciences APR Few were familiar with APR or similar processes Majority (4) were involved in what they consider to be a major curriculum change Of those 4 most stated the change was positive for the department and students, one sated the change was a formality with no substantive effect on department or students Off cuff statements include the idea that program review and change at UD is not looked upon with great value and another stated that curriculum review and change over the years and institutions is the same but with different names

One response to the increased class size is the demand for more graduate Teaching Assistants with a greater role in the teaching load as noted "Once in a while you feel like some help in grading would be helpful..... When someone takes sabbatical and your class swells..... above 50 students". And also that "It used to be that all grad students had to TA [teaching assist], but once the department focused on principal research the number of TA's dropped". One interviewee had a possible answer to the issue as they stated "I spent a lot of time learning how to use undergraduates in a class. I learned how to efficiently use undergrads as TA's. I think the [large enrollment courses] could definitely benefit form peer leader in those courses".

As for faculty instructional development, the argument is that the workload is too heavy and that instructional development and/or educational research is not seen as equivalent to primary scientific research. One respondent stated "the dept. should be more supportive of getting external funding of teaching based projects". Another states "workload time for course and program assessment should be carved out.... if I say I want to do an assessment of this class, I think they should say here is so many credits of adjustment to your workload".

Finally, two respondents noted the lack of instructional mentoring and the wish to re-instate the method "I like the recommendations for teaching support but I'd prefer hands on experience with instruction. Currently there is no mentoring being done, I think that it is out of convenience". The second responder noted, "This department does have this formal mentor mentee teaching sort of thing. I have done this as well to incoming faculty. I did get credit for it because you sit through the other faculty lectures and it takes time. If they ask I think all the assistant faculty, all should have this mentorship". For further review, the findings have been summarized in Table 4G.

Limitations

The limitations for the study are applicable to any program review. Though the faculty who participated in the interview covered all the core-required courses, for several of the courses there was only one interviewee per course. This makes for a very one-sided perspective on the course content and student skills development. The interview participants may not reflect the greater population of instructors. In this study 7 individuals participated out of a possible pool of 20 that met the inclusion criteria. Being only about one-third of the total, it cannot even be said that any singular perspective is in the majority of the total faculty pool. In fact the quantitative data coming from the survey is again practically only qualitative. There are not enough data points to run any statistics for regression, correlation or any other manner of analysis. The data stands alone in tables as trends, open for interpretation that may be inaccurate. Preferred analysis would include grouping of responses by the demographic data, but at that point it would only be comparing one person's perspective to another. Having the time to approach more faculty members and include their insight into the qualitative and quantitative data so that there were multiple respondents per course would be optimal.

Summary

The University of Delaware Department of Biological Sciences is perceived by faculty to have some favorable and less favorable components. Those components may be tempered by the experiences of each individual faculty member and their teaching habits. Three faculty had stated they had been through an intensive curriculum change. Overall the university has an excellent resource in the CTAL and financial backing of instructional development. This resource in the past has been recommended by the chair and administration within the Department of Biological Sciences. Often the department finances off site instructional development or research conference attendance for the purpose of advancing the knowledge of the faculty within their field of interest to benefit student outcomes. The faculty feel the core required courses should remain required, no courses are seen as extraneous, however there was a general sense that developmental biology and ecology should be added. Overall the department offers majors and concentrations that are comparable to peer institutions, though it seems the department is working within its strengths and could possibly branch out in the future to include more evolution and ecology related majors.

Overall, the faculty agreed with the inclusion of the AAAS recommendations for content and argued that most classes focused at some level on all 5 content areas. Most faculty also agreed that the AAAS goals commonly overlapped with the University of Delaware General Education goals, and felt that General Education goals would be met coincidentally by covering the AAAS goals. Unfortunately, few faculty stated they use the AAAS content goals while considering student outcomes for courses. And no faculty stated they use the AAAS or general education skills goals during course design.

One area where the department could improve efforts would be in valuing teaching and instructional development. Many faculty stated increased teaching workload and responsibility were not factored into promotion and tenure discussions. Several noted large class sizes or not being able to provide individual attention to struggling students. Interviewees also commented that neither time, credit nor pay was allotted to allow for program evaluation besides those needed for accreditation.

The recommendations to the Department of Biological Sciences from this analysis are as follows, (1) Greater emphasis should be put on the excellent available resources from the CTAL, (2) Teaching responsibility and instructional development should be considered more valuable during promotion and tenure decisions, (3) Faculty should consider student skills attainment when reformatting or creating courses, whether those come from AAAS, general education or personal faculty research, (4) A greater emphasis should be placed on 21st century pedagogical practices, and finally (5) there is a shared opinion from within the interviewed faculty that the department should undertake another academic program review, or allow for more frequent smaller internal reviews.

Attachments to Faculty Perception of University of Delaware Department of Biological Sciences Alignment and Delivery of Curriculum and Pedagogy Handouts for consideration during the faculty interviews.

Attachment 1: Questions for Core Course Faculty based AAAS *Vision and Change* and previous Academic Program Review (APR).

After analyzing the AAAS *Vision and Change* document as well as the previous APR and Mapping UD Courses to the General Education Objectives, the following questions have been created to gauge faculty opinion on how well the department has met the AAAS national recommendations and how the department has bought into faculty development.

Theme 1: Core Curriculum

- Do you consider your course to be part the "Core Curriculum"?

Reference Handout for BISC833 Core Required Courses for following questions:

- Currently there are --- required core courses (list them). Do you agree that these should continue to be included in the required core or not?

  -Why do you think so?
- Do you think this department is lacking in core courses?

  -If so, to what are you making this comparison? Other Institutions? Literature? Etc.

Theme 2: APR and Curriculum Change

- Who do you think is most affected by a curriculum change? (keep probing)

  -Who do you think should be consulted in the event that changes are done?

  -Who else?

- What knowledge do you have of the most recent University of Delaware Department of Biological Sciences APR and the documents used within?
- What are you currently doing with your course to ensure that it includes nationally recommended content and skills?

  -Is what your doing adequate?

  -What resources do you need and have used to make changes?

  -What resources do you need and wish to have available to support these changes? (probe)

- What tangible changes to the core curriculum, if any, have you seen in the last few years?

  -What do you think of these changes?

Reference Handout for AAAS Vision and Change for following questions:

Narrative: "I have some documents for you to view and consider before answering the following questions."

- Starting with content recommended by AAAS *Vision and Change*, how well would you say your core required class covers the concepts?

  -If multiple courses, please note which class covers which concepts.

- When it comes to student learning, what type of assessments do you use?

  -Have you experimented with other forms of assessment?

-If yes, what types? Which ones have you found to be most useful indicators of student learning?

-If no, why not?

-Has your assessment type been influenced by recent curriculum change?

- How well do you believe your core required course equips the students with the recommended skills attained by undergraduates?
- If you believe your course equips students with skills outcomes, do you formally assess skills attainment?

-What assessment do you use, practical, exams, recorded observation?

- Which courses in the core curriculum are best suited to assess skill attainment?

-Why these selected courses specifically.

-If they mention their course follow-up and ask how, if they don't mention it ask why they did not.

Reference Handout for General Education Outcomes for following questions:

- Are you familiar with the most recent change to General Education Outcomes?

-Do the Gen Ed outcomes affect how you plan or teach your courses?

- Did you participate in the faculty survey involving the map analysis?

-If so, how did you score the alignment of your class?

-If not, how would you rate your course alignment with the general education goals?

- Do you feel the Gen Ed goals and Vision and Change goals overlap?
- Do you feel there is a priority for either Gen Ed goals or AAAS goals?

-If so, which has higher priority? Please provide a rational/explanation

Theme 3: Supports for Advancing Teacher Pedagogy for Student Learning Outcome Success.

3a: Administrative Assistance

- Are you aware of any administrative assistance for faculty instructional development?
- Have you utilized any administrative assistance?

  -CTE, CTAL, CIRTL?
- If so, was it budgeted, supported supplemented, recommended by administration?
- How productive was that experience for you? To what extent were you satisfied? What was most useful in terms of effecting changes in the course or in your teaching? At what level? What was least useful? (probe answers)

3b: Outside Department/Institute

- Were you trained in instruction prior to coming to the University of Delaware?
- Since joining UD, have you attended a conference/workshop to improve your instruction?

  -If so was it useful?
- Have you used materials/concepts gained from these experiences in your instruction? If yes, what did they use? If no, why not?

Demographics

- Which courses have you taught?
- How many years have you taught?
- Have you been part of preparing an APR?
- Have you experienced curriculum change before?

  -What was the scale of the change?

  -How did it affect your instruction?

  -What were some of the pros and cons for that change?

Attachment 2: List of Core Courses Originating form BISC833 Biology Curricula Review

Introductory Biology I (BISC207)

Introductory Biology II (BISC208)

Cell Biology (BISC305)

General Physiology (BISC306)

Molecular Biology of the Cell (BISC401)

Genetic and Evolutionary Biology (BISC403)

Attachment 3: Student Outcome Recommendations from the AAAS *Vision and Change* Document

According to the AAAS, for a student to be biologically literate, he or she needs to have an understanding of five core concepts. These are:

(1) Evolution

(2) Structure and Function

(3) Information Flow

(4) Pathways and Transformation of Energy

(5) Systems.

The report calls for these core concepts to be integrated with core competencies and disciplinary practices including:

(1) the ability to apply the process of science

(2) the ability to use quantitative reasoning

(3) the ability to use modeling and simulation

(4) the ability to tap into the interdisciplinary nature of science

(5) the ability to communicate and collaborate with other disciplines

(6) the ability to understand relationships between science and society.

Below are tables for you to fill out when considering how well your course(s) cover the content and skills recommended by the AAAS *Vision and Change* document.

Concept	Covered well	Covered somewhat	Not covered at all
Evolution			
Structure and Function			
Information Flow			
Pathways and Transformation of Energy			
Systems.			

Ability to :	Covered well	Covered somewhat	Not covered at all
Apply the process of science			
Use quantitative reasoning			
Use modeling and simulation			
Tap into the interdisciplinary nature of science			
Communicate and collaborate with other disciplines			
Understand relationships between science and society			

Attachment 4: Student Outcome Recommendations from the University of Delaware General Education Reform Committee Document

Source: http://sites.udel.edu/gened/

At the University of Delaware, General Education sets students along the path of possessing a complete set of characteristics of one who is both broadly and deeply educated. We seek to prepare students who are:

- Engaged citizens, involved in the world around them, and who understand the major challenges and debates of the day;
- Aware of their intellectual strengths and interests and of their ethical values and commitments;
- Capable of interpreting the arts and culture of contemporary and past societies; and,
- Equipped with the essential skills necessary to thrive in a rapidly evolving world including the ability to be a lifelong learner, creator, and innovator.

To fulfill these purposes, major requirements and general education requirements are combined to meet five objectives. We seek to prepare students who are able to:

1. Read critically, analyze arguments and information, and engage in constructive ideation.
2. Communicate effectively in writing, orally, and through creative expression.
3. Work collaboratively and independently within and across a variety of cultural contexts and a spectrum of differences.
4. Critically evaluate the ethical implications of what they say and do.
5. Reason quantitatively, computationally, and scientifically.

Attachment 5: Recruitment Email for Faculty Interviews

Dear (name of participant)

My name is Benjamin Rohe, researcher and adjunct faculty in the Department of Biological Sciences. The purpose of the message is to invite you to participate in a research study. You are one of approximately 12 participants who are asked to participate in this study because you have been listed in the University of Delaware Course Catalogue as an instructor of record in a core biology course, one or several of those listed here: BISC207; BISC208; BISC305; BISC306; BISC401 and/or BISC403.

The purpose of this study is to determine the perceptions of the faculty in the Department of Biological Sciences towards curriculum change, its effects on stakeholders such as students and educators and the range of teaching methods currently in use. The results of the study will be used in an Educational Leadership Portfolio, which is a graduation requirement for the Educational Leadership program.

As part of this study you will be asked to sit for an interview to discuss your perceptions of the content and skills learned by students in your core biology course(s). Topics will also cover any curriculum change you have been through and any professional development you have undergone for instructing biology. The interviews will take place in an office or conference room setting of your choosing for roughly 30 to 45 minutes, to allow enough time to discuss all the topics.

If you wish to participate or have any questions about this study, please contact:

Benjamin Rohe (researcher) at (302) 831-1291 or bgroh@udel.edu

Dr. Zoubeida Dagher (advisor) at (302) 831-1667 or zoubeida@udel.edu

If you have any questions or concerns about your rights as a research participant, you may contact the University of Delaware Institutional Review Board at hsrb-research@udel.edu or (302) 831-2137.

I look forward to hearing from you,

Signature

Attachment 6: Consent Form for Faculty Interview

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

Title of Project: Faculty Interviews for Curriculum in Biology

Principal Investigator(s): Benjamin G. Rohe M.S., Ed.D. Candidate

You are being invited to participate in a research study. This consent form tells you about the study including its purpose, what you will be asked to do if you decide to take part, and the risks and benefits of being in the study. Please read the information below and ask us any questions you may have before you decide whether or not you agree to participate.

WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of this study is to determine the faculty perceptions of curriculum change, its effects on stakeholders such as students and educators and which methods of teaching are being used at the University Of Delaware Department Of Biological Sciences. The results of the study will be used in an Educational Leadership Portfolio, which must be completed for graduation in the Educational Doctorate program.

You will be one of approximately 12 participants in this study. You are being asked to participate because you have been listed in the University of Delaware Course Catalogue as an instructor of record in a core biology course, one or several of those listed here: BISC207; BISC208; BISC305; BISC306; BISC401 and/or BISC403.

An individual may be excluded from participating if they find it uncomfortable to sit through a 30-45 minute interview process and complete a short survey.

WHAT WILL YOU BE ASKED TO DO?

As part of this study you will be asked to sit for an interview regarding your perception of the content and skills learned by students in your core biology course. Topics will also cover any curriculum change you have been through and any professional development you have undergone for instructing biology. The one time sound recorded interviews will take place in an office or conference room setting of your choosing for roughly 30 to 45 minutes, giving proper time to discuss all the topics. Brief surveys will be completed to assist the recordings analysis and create a summary of the interview.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

The research team does not expect your participation in this study will expose you to any risks different from those you would encounter in daily life.

WHAT ARE THE POTENTIAL BENEFITS?

You will not benefit directly from taking part in this research. However, the knowledge gained from this study may contribute to our understanding of undergraduate student learning outcomes from the department of Biological Sciences at the University of Delaware.

NEW INFORMATION THAT COULD AFFECT YOUR PARTICIPATION:

During the course of this study we may learn new information that could be important to you. This may include information that could cause you to change your mind about participating in the study. We will notify you as soon as possible if any new information becomes available.

HOW WILL CONFIDENTIALITY BE MAINTAINED? WHO MAY KNOW THAT YOU PARTICIPATED IN THIS RESEARCH?

Participants' information will be confidential.

The research team will keep information learned about you confidential to the extent possible. We cannot promise that information shared with other study participants during the focus groups will be kept confidential.

Paper copies of the surveys and transcripts of the interviews will be kept in a locked cabinet in a locked office when not being analyzed.

Electronic copies of recordings and interviews will be maintained on a security coded computers and only accessible to researches pertinent to the study.

Results of the study will be reported in the Educational Leadership Portfolio as required for completion of the Educational Doctorate program at the University of Delaware. The research team will make every effort to keep all research records that identify you confidential. The findings of this research may be presented or published. If this happens, no information that gives your name or other details will be shared.

Participation in this study requires a voice recording of the interview which will only be heard by study personnel, researchers and professional audiences. Recordings will be kept indefinitely.

The confidentiality of your records will be protected to the extent permitted by law. Your research records may be viewed by the University of Delaware Institutional Review Board, which is a committee formally designated to approve, monitor, and review biomedical and behavioral research involving humans. Records relating to this research will be kept for at least three years after the research study has been completed.

USE OF DATA COLLECTED FROM YOU IN FUTURE RESEARCH:

The research data we will be collecting from you during your participation in this study may be useful in other research studies in the future. Your choice about future use of your data will have no impact on your participation in this research study. Do we have your permission to use in future studies data collected from you? Please write your initials next to your preferred choice.

________ **YES** ________ **NO**

WILL THERE BE ANY COSTS TO YOU FOR PARTICIPATING IN THIS RESEARCH?

There are no costs associated with participating in the study.

WILL YOU RECEIVE ANY COMPENSATION FOR PARTICIPATION?

There is no compensation.

DO YOU HAVE TO TAKE PART IN THIS STUDY?

Taking part in this research study is entirely voluntary. You do not have to participate in this research. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled. Your decision to stop participation, or not to participate, will not influence current or future relationships with the University of Delaware.

If, at any time, you decide to end your participation in this research study, please inform our research team by telling the investigator(s).

FINANCIAL INTEREST(S) OF THE RESEARCHERS:

Investigators of this research have a financial association with the sponsor of this project. This relationship has been disclosed to the University and it is being managed to avoid potential conflicts of interest.

WHO SHOULD YOU CALL IF YOU HAVE QUESTIONS OR CONCERNS?

If you have any questions about this study, please contact the Principal Investigator, _Benjamin G. Rohe___, at (302) 831-1291 or bgroh@udel.edu or _Dr. Zoubeida Dagher_, at (302) 831-1667 or Zoubeida@udel.edu .

If you have any questions or concerns about your rights as a research participant, you may contact the University of Delaware Institutional Review Board at hsrb-research@udel.edu or (302) 831-2137.

Your signature on this form means that: 1) you are at least 18 years old; 2) you have read and understand the information given in this form; 3) you have asked any questions you have about the research and the questions have been answered to your satisfaction; and 4) you accept the terms in the form and volunteer to participate in the study. You will be given a copy of this form to keep.

_______________________________ ___________________________ __________

Printed Name of Participant Signature of Participant Date

_______________________________ ___________________________ __________

Person Obtaining Consent Person Obtaining Consent Date

(PRINTED NAME) (SIGNATURE)

OPTIONAL CONSENT TO BE CONTACTED FOR FUTURE STUDIES:

Do we have your permission to contact you regarding participation in future studies? Please write your initials next to your preferred choice.

________ YES ________ NO

Appendix H

REVIEW OF BIOLOGY PEDAGOGY AND CURRICULUM TRENDS

Context

Vision and Change in Undergraduate Biology Education: A call to Action, was used within the University of Delaware's Department of Biological Sciences most recent Academic Program Review (2012) to model the aspirational content and skills that should be attained by a student graduating from the department. Student interviews that were conducted to complete the *Vision and Change* document concluded that lecture is the worst possible method of instruction for student outcomes according to student opinion (Brewer & Smith, 2012). This argument has been backed by research, which shows that an un-stimulating learning environment will lead to less learning (Handelsman, Miller & Pfund, 2007). Mary Allen Gleason argued that a large classroom, the chance for student anonymity, a sage on the stage and theater seating all create the least stimulating method of teaching and therefore the least effective (Gleason, 1986).

It is necessary to change the pattern in which instructors teach to create a more stimulating, engaging environment. This constitutes a curriculum change in a major way. The focus of this artifact is to document the change in the setting of the university over the past 100 years in response to cultural demands and compare the three most recent "calls for action" from the American Association for the Advancement of Science (AAAS) and the National Academy of Science (NAS) to counter the growing class sizes and ineffectiveness of the lecture hall. Since the AAAS document was not a blank sheet creation it is wise to review two prior efforts, the *Science for all Americans* document which focuses largely in K-12, and the

BIO2010 document for undergraduate study from the national committees and foundations for comparison purposes.

Creation of the American University

It is well documented that the current American university model is an adaptation of the European university. These European universities had two models, the faculty centered and the student centered with prime examples at Paris and Bologna respectively. It was at these colonial universities that students learned from a small body of faculty, usually one president and a handful of faculty that taught the tenet courses of logic, ethics, physics, metaphysics, astronomy, mathematics and rhetoric using the ancient languages of Latin and Greek as a living language in which learning and discussion took place (Haskins, 1957).

The history of this curriculum is present to this day in the University of Delaware seal, as it symbolizes one of the earliest University of Delaware course catalogues. The seal consists of a ring signifying it as the seal of the University of Delaware "Sigillum Universitatis Delavariensis", a banner stating knowledge is the light of the mind "Scientia Sol Mentis Est" and an open book with the words Gramm, Philol, Rhetor, Ethica, Metaph, Logica, Mathem, Physica inscribed representing the first course catalogue of the University of Delaware (University of Delaware, 2017). Missing from the University of Delaware course catalogue is theology, which was offered as a core class at most of the early institutions as they were still rooted deeply in either the Church of England or Puritanism. As it were, a majority of graduates became ministers in the respective college religions (Haskins, 1957). Biology or the natural Sciences in general is also missing, it may have been contained within the Philosophy as the understanding of human actions and living, but it was not the evidence based science as we know it, as it would counter the religious underpinnings of the colonial university.

Near the time of the American Revolution the colleges took on the political challenges. The curriculum became that of educating for the republic that now included much more science and reason into the usual theology. According to David Robson (1985) this was viewed as the education of republican Christian Enlightenment. Turmoil followed in the early decades of the 1800's as the curriculum attempted to change back to exclude modern science and thought. The turmoil was seen as a result of the new topics, colleges reverted back to classical languages study and the hopes for an education including biology was once again de-railed, however a few colleges continued to teach related sciences in the professional class with a pre-professional curriculum. Those were unfortunately seen as lower forms of education.

Turn of the Century to mid 1900's

By the end of the 19th century, a uniting effort was put forth bolstered by the first and second Morrill Land-Grant act of 1862 and 1890, seemed to create the template for a "university" that followed a familiar German university concept. The curriculum now included agricultural, mechanical and natural sciences, the liberal arts, classical studies and mathematics as the foundation. In this curriculum one can begin to see the underpinnings of Biology as a topic of study, the concepts of zoology, botany and physiology however were still separate courses. The student body grew with addition of graduate education departments and colleges within universities (Geiger, 2016).

At this time many institutions and foundations also started to support the growing universities both financially through funding pensions and endowments and to standardize the education. These included the Carnegie Foundation for the Advancement of Teaching, the General Education Board, American Association of University Professors, National Association of State Universities and the Association of American Universities (Altbach, Berdahl & Gumport 2005).

During this time the field of biology was relatively new at least as thought of under that name. Taken into account that biology is the study of life and teachings on life have been ongoing since Plato and Aristotle (Freeman, Allison, Black, Podgorski, Quillin, Monroe & Taylor, 2017). Henry Martin at Johns Hopkins University first introduced biology as a stand-alone course, after he published a text with John Huxley at the end of the 19th Century (Rosenthal, 1990). Some have argued that is was the fraction of general sciences classes that separated biology from chemistry, as Darwinian thought, Mendelian genetics, the scientific method and the inclusion of statistics differentiated biology from the material production focus of chemists of the age (Allen, 1979). While the budding introductory biology course started to consolidate the material, according to Christy the courses still suffered from a glut of technical information and rote memorization (Christy, 1936).

While the other arts and humanities began to grow with a stronger focus on human experience, the idea of the learners' experience seemed less important in biology. John Locke and Dewey previously argued for a better system of learning from 17th to 20th century (Hayes, 2006). But the pedagogy of teaching biology was stuck in the medical field that had a greater emphasis on training or conditioning, than to allow for free thought. Teaching biology has been happening the same way since the process was diagnosed by several researchers over the past century, Christy in 1936, McKibben in 1947, Bybee in 1977, and Harms and Yager in 1981 (Rosenthal, 1990). According to Rosenthal, there has always been a knowledge component (content), methods component (skills), as well as a personal and social component. Sometimes with varying degrees, but the components were always there since biology-focused content had been offered in a stand-alone course (Rosenthal, 1990).

The one thing that did change however was the content of biology courses. As biological research continued, textbooks were updated and evidence was included that bolstered previous concepts. The mid to late 20^{th} century brought the genetic age with Watson, Crick and Franklin and other exciting advancements in knowledge. But one thing remained, the method of educating students in these disciplines stagnated as instructors lectured and students listened through lecture and performed canned exercises in the laboratory (Brewer & Smith, 2011).

The status quo was stimulus and response or assign and test, the argument being that within the hard sciences such as biology, chemistry, physics and engineering instructors should be the expert in the field and pass on knowledge, it was not necessary that they be great educators. It is this issue that we are still dealing with to this day. It seems the face of teaching much of the biology has yet to return to methods of Socrates, Dewey or the other great educational progressivists.

The University Post World War II

Although the content within a biology class was already determined by the culture and economics of the early 1900's (Goldin & Katz, 1990), the university setting was about to take on another complication that would make one on one meaningful and enlightening instruction rather difficult. World War II, more specifically the end of WWII, stagnated the development of teaching of biology by way of the Servicemen's Readjustment Act of 1944 (G.I. Bill) that allowed for 2 million veterans to take advantage of paid tuition in nearly a 5-year time period.

For most colleges, that equated to a doubling or tripling of the student body. This influx of students continued as the baby boomer generation flooded colleges again in the 1960's. This population growth molded the methods of teaching into that which we know of today as the college classroom (Altbach, Berdahl & Gumport, 2005). Though it was well known that the lecture was not an effective means of learning for students, the Socratic dialogue method of reading and discussion just did not seem to fit in the crowded lecture hall.

The 1960 college classroom is typified by a large lecture hall with greater than 100 students listening quietly as the expert in the field or at least a lecturer highly educated on the subject espouses content (Gleason, 1986). In previous instances of collegiate growth there was no sacrifice to the curriculum. However in this time period many colleges used administrative means to manage the overcrowded classrooms. The year-round schedule was created, class meetings were shortened to make for more meetings and the requirements for completion were lowered (Altbach, Berdahl & Gumport, 2005).

Compounding the issue in already swollen classrooms, the interest in the sciences at the time hit a high mark as Sputnik led to the space race and a push to reform the sciences. The future seemed to be in the sciences, and the National Science Foundation, National Institutes of Health and National Aeronautical Space Administration financially fueled the reform. However, the effort was rushed and too strongly focused on computer sciences and technology. According to F. James Rutherford, there were some lessons to be learned from this rapid reform. He argues that when a concerted group effort is put forth to attain a goal it can bring about great change. However, after the goal was attained, there was nothing left to shoot for. This led to a rapid and prolonged moment of silence from those original drivers of education reform (Rutherford, 1997).

This trend continued into the mid 1970's, until finally a counter-culture rose through colleges and universities with a focus on civil rights and anti-war sentiment. Interest in science in general, biology included, waned, as most students graduating in the 1980's with bachelor's degrees from business departments or colleges (Altbach, Berdahl & Gumport, 2005). The stagnation of growth was not only in the student body, there was also a hold on the advancement of teaching knowledge, skills and techniques. Lecturing content to a large class was still the method of choice. Technology in the classroom had not advanced much from the giant boom of the 1950's. Student assessment was based on exams and written assignments that were favored early on by the technological sciences, when skill and knowledge acquisition was of utmost importance.

Evidence for national reflection on science education in the 1980's can be seen in the document that many organizations regarded as the new standard published *Science for All Americans* in 1989 (Rutherford, 1990). Within *Science for all Americans* and the previous document *A Nation at Risk* the argument for science education reform falls on the economic woes (Gardner, 1983). The document argues that the United States at that time was in an economic quagmire, falling from the high of technological advancement from the space race and cold war, into the postindustrial age. The report cites falling test scores and lack of interest in the sciences highlight the need for overall education reform but specifically for the sciences, mathematics and technology. This document does make some compelling arguments that reform in sciences should be collaborative, teachers are essential for helping reform, comprehensive approaches were necessary, focus must be on science learning needs of all children and positive conditions for the reform must be established.

The recommendations from this document were that top officials show buy in to the process, from President and Congress to professional societies such as National Science Teachers Association, National Council of Teachers and so forth take the educational leadership role. Though this is the model for K-12 teacher education, it was not long before the model was used in the Higher Education setting. It is this concept that was carried on in the *Bio2010* and *Vision and Change* documents as well as other documents of the time that argued for higher education instructor training in pedagogy and curriculum.

The Next Millennium and Curriculum Reform: the response to the sage on the stage

Through the 1990's and early 2000's computers worked their way into the classroom. Written assignments were being created in word processing platforms, and eventually electronic slide presentation software became beloved by instructors and eventually despised by students. As a response to the initial call to action from the American Association for the Advancement of Science that asked the national societies for leadership and financial assistance (Brewer & Smith, 2011). The National Institutes of Health (NIH), National Science Foundation (NSF) and National Aeronautics and Space Administration (NASA) research grants provided funding for undergraduate research and teacher education in pedagogy from Howard Hughes Medical Institute, the American Association for the Advancement of Science and the National Science Foundation.

This financial support aimed at improving the college student learning outcomes by way of implementing a new method of instruction in two proposed methods; 1) there was a push to create a system of education through student centered learning, and 2) there was an effort to improve the teaching methods of educators. The following is a review of efforts that were put in place to train higher education instructors and offer a new face to teaching science in colleges and universities from the late 20th century into the 21st. Though this document is not meant to be a total compendium on successful practices in biology education, it is important to note that an entire field of discipline based educational research (DBER) exists (Singer, Nielsen & Schweingruber, 2017). Below are evidence based historical instructional and curriculum changes based on those in the AAAS *Vision and Change* document with supporting material. A more in depth analysis of the *Vision and Change* document is available (Appendix C) with the most recent available educational research investigations supporting the recommendations from AAAS.

Introducing changes to instruction methodology

According to the University of Delaware Institute for Transforming Undergraduate Education (ITUE) which was implemented early in the lifetime of PBL courses, the changes in methods of communication at the time meant the undergraduates needed to learn new and improved skills in reasoning and communication to help them succeed (Duch, Groh & Allen 2001). Problem Based Learning (PBL) was developing at this time in the undergraduate life sciences. In these types of classes the course may be considered flipped, one in which material is learned by students reading prior to coming to class and class time is used for discussion or problem solving, or the problem could open the semester and the students spend most of class time throughout the semester working collaboratively towards a solution (Boud, 1985). In some of the more advanced classes there may not even be a known answer to the problem, in that instance assessment is not merely how close the student gets to the correct answer, but evaluating the thought process and logical arguments.

Problem based learning in the sciences at the University of Delaware began in the early 1990's when the University of Delaware, through a joint collaboration between the University of Delaware and Thomas Jefferson Medical College, instituted the Medical Scholars program. The PBL curriculum gained popularity and stakeholders as the Center for Teaching Effectiveness held workshops on the new instructional strategy (Groh, Williams, Allen, Duch, Mierson, & White, 1996). According to the authors, those involved in the budding program recognized the fact that change is difficult and often faculty resisted. Successful institutionalization of new techniques and curriculum requires encouragement and support from administration involved in faculty development (Groh et al., 1996). But when the effort was put in, students were now reaching higher on

Blooms taxanomic scale and analyzing problems, creating possible solutions, and evaluating one another's solutions to determine which is best.

Another recommended method for higher student learning is by utilizing concept maps. Concept mapping was introduced to higher education when the pioneer Joseph Novak used it to create meaning with the material in undergraduate teaching classes at Cornell University in the 70's and 80's (Novak, 1990). Its use in undergraduate biology courses has been tested for efficacy and effectiveness. For example, Briscoe and LaMaster (1991) conducted a study to answer two questions, how students used concept maps in undergraduate biology and what influenced the way student made and used the maps. The authors found that students generally only used concept mapping when instructed or when it was included as a graded assessment. The good news is even though few students used concept mapping, when they did it was determined they were using concept mapping for managing higher level applications like problem solving and generally creating more meaningful learning (Briscoe & LaMaster, 1991).

Importance of Student Engagement

Student engagement has been studied and been shown to be beneficial (Ahlfeldt, Mehta & Sellnow, 2005). While Ahlfeldt et al.'s study was particularly on PBL classrooms, they provide statistical evidence that engagement is greatest in small enrollment, upper-level classrooms, yet they recommended it should be applied as early and often as possible as the results can only be positive (2005). A meta-analysis on publications pitting lecturing versus active learning shows that active learning increases exam scores by 6%, and that students in courses based heavily on lecture were 1.5 times more likely to fail (Freeman, Eddy, McDonough, Smith, Okoroafor & Jordt, 2014). In this meta-analysis study, the active learning methods included such techniques as group work/problem solving, worksheets or tutorials completed in class, personal response systems such as iclicker and studio/workshop time.

Specifically in introductory biology courses, active learning which could include so little as 5 minutes spent in a group on a problem with instructor prodding and a student centered focus lead to greater student satisfaction in lectures (Armbruster, Patel, Johnson & Weiss, 2009). In Armbruster et al.'s study student learning outcomes and instructor quality improved with just a short period of active learning as reported by students at semester end evaluations (Armbruster et al., 2009). The same study showed student performance also improved significantly on the final exam.

Similar studies have shown performance gains for students that are at higher risk for poor performance when utilizing active learning in introductory biology courses (Freeman, O'Conner, Parks, Cunningham, Hurley, Haak, Dirks & Wenderoth, 2007). The Freeman et al. study also noted that these particular active learning instructional techniques lowered the overall fail/withdraw rate (Freeman et al., 2007). And for clarification, the student-centered pedagogy, requires a greater amount of transparency. Armbruster, Johnson and Weiss (2009) made clear connections between the learning outcomes and the content and activities by presenting them to the students in powerpoint prior to beginning the class. The authors also state that it required a number of times for feedback from the group work, the homework, and formative assessments that allowed students to self monitor as well in "low stakes" assignments (Armbuster et al., 2009).

Changing the Curriculum for Future Scientists

As the above strategies for reforming undergraduate biology education were slowly taking hold in the lecture halls early in the 21st century, several forward thinking science educators saw the stagnation in laboratory instruction and conferred on how to make it better. The result of this project was the book *BIO2010: Transforming Undergraduate Education for Future Research Biologists* published by the National Research Council of the National Academies (2003). The emphasis from the *Bio2010* document was on preparing undergraduate students for research experiences. As the committee discussed and transcribed the needs, demands and expected skills of the budding scientist, it was noted that scientific inquiry defined as observation, hypothesis creation, testing and analysis, be the driving force for future science education with a focus on interdisciplinary and collaborative research. A strong emphasis was put on undergraduate research so students would "learn the same way scientists learn –through research" (National Research Council, 2003). *BIO2010* offered recommendations to change the course sequence to include Independent Laboratory Research in the last 4 semesters of the undergraduate curriculum. It also strongly recommended a course titled Faculty Research Seminar, in which Research Faculty offer class long lectures on their research to the entire freshman class of natural science or biomedical science majors, which would orient the students with the possibilities for junior and senior year research.

There are initial concerns that arose with this recommended curriculum change, most importantly funding. First there is the need for course creation, and faculty buy in to the concept. The faculty would also need training on how to teach undergraduates to perform research and guide them through the inquiry process and learn the critical thinking skills necessary. Luckily the *BIO2010* document offered resources for all those concerns with exemplary case studies and recommendations for faculty development either on or off site. *Bio2010* does suggest that HHMI and NSF and other funding bodies would offer financial support for undergraduate research.

As an example, the University of Delaware had maintained a relationship with HHMI that resulted in decades of funded undergraduate research. However, recently the grant was not re-attained and the strain was felt most on undergraduate research opportunity. Concurrently, the biomedical research field was dealing with a budget cut from its previous late 1990's highs. This posed a problem for the recommendations from the *BIO2010* document; there were not enough opportunities within the institution for independent research for all biomedical majoring juniors and seniors.

Few higher education institutions such as Princeton University could maintain undergraduate research for all majors because of small student bodies, high tuition costs, and the acclaim of their faculty to gain grant funding. However, for the larger, less elite institutions, many began relying on the biotech boom to fund the undergraduate research. Some research labs and departments formed affiliations with local biotech firms, often with cooperating alums (Altbach, Berdahl & Gumport, 2005). Yet again as with the dotcom bubble, many affiliations faded or busted with small biotech companies being bought out by larger ones.

It turns out one possible replacement for the independent research in a less than opportune environment was the experiential learning laboratory. A course for credit runs less like a cut and paste cook-book style introductory lab class. Instead, it is project driven course that sometimes offers help to research faculty by doing some of the less technical aspects of genetic, proteomic or molecular biology research such as cloning or western blotting for results analysis. The students participate in a small step of the overall research project, yet can learn many of the techniques or skills and become aware of the realities, difficulties and pitfalls of research science.

According to one study, surveys completed after a curriculum that included experiential labs in cell biology showed students improved in several scientific skills, students often self reflected on their skills prior to the course, students found the projects relevant, and importantly the projects helped accomplish the course goals and strengthened content acquisition (DebBurman, 2002). Another program with similar results is the semester long project. One particular study found that incorporating a semester long project in a large introductory biology class exposes students to troubleshooting their own data and ideas, as well keeps them engaged and had students reporting an interest in taking future courses in research and experimental design (Treacy, Sankaran, Gordon-Messer, Saly, Miller, Isaac & Kosinski-Collins, 2011).

These types of courses highlight the most recent shifts in the concept of teaching that involve the student in a metacognitive process. That is making students think about and understand how they learn, and which processes work best for them, be it active learning, peer led discussion or tutoring, simple autodidactic processes, or visual learning through example videos or watching a professional at work. Recent advances in technology allow instructors to use tech for more than simply presenting material. Small changes came in the form of videos played during class.

Additionally, interactive quizzes began to be used outside the lecture period by students with computers and internet connectivity. Finally, some technology allowed real time assessment during the lecture, such as clicker quizzes, polling and rating (Altbach, Berdahl & Gumport, 2005). This quickly allowed instructors to notice points of contention or misunderstanding in real time, during the lecture/discussion session. One of the simplest things to do was then to immediately address the misconceptions and correct the thought process and incorrect previous knowledge leading to the misunderstanding.

The AAAS document *Vision and Change* brought these topics to light in the realm of biology education. Where *Bio2010* recognized that an engaged, interested student would better learn the content, *Vision and Change* took the concept one step further and outlined the target content and skills any biology graduate should understand and demonstrate.

References

Ahhlfeldt, S., Mehta, S., Sellnow, T. (2005). Measurement and analysis of student engagement in university classes where varying levels of PBL methods of instruction are in use. *Higher Education Research & Develop*ment. *24* (1), 5-20.

Allen, G. (1979). *The transformation of a science: T. H. Morgan and the emergence of a new American biology*. The organization of knowledge in modern America, 1860–1920. Baltimore, MD: Johns Hopkins University Press.

Altbach, P.G., Berdahl, R.O., Gumport, P.J. (2005). *American higher education in the twenty-first century. Social, political, and economic challenges*. Baltimore, MD.: The Johns Hopkins University Press.

Armbruster, P., Patel, M., Johnson, E., Weiss, M. (2009). Active learning and student centered pedagogy improve student attitudes and performance in introductory biology. *CBE- Life Sciences Education. 8*, 203-213.

Brewer, C. & Smith, D. (2011). *Vision and change in undergraduate biology education* (1st ed.). Washington, D.C.: American Association for the Advancement of Science.

Briscoe, C. & LaMaster, S.U. (1991). Meaningful learning in college biology through concept mapping. *The American Biology Teacher, 53*(4). University of California Press on behalf of the National Association of Biology Teachers.

Boud, D. (1985). *Problem-based learning for the professions.* Sydney. HERDSA.

Christy, O.B. (1936). *The development of the teaching of general biology in the secondary schools (Peabody Contribution to Education No. 201*). Nashville: George Peabody College for Teachers.

DebBurman, S. K. (2002). Learning how scientists work: Experiential research projects to promote cell biology learning and scientific process skills. *Cell Biology Education, 1*, 154-172.

Duch, B.J, Groh, S. E., Allen, D. E. (2001). *The power of problem-based learning.* Sterling, Virginia: Stylus.

Freeman, S., Allison, L. A., Black, M., Podgorski, G., Quillin, K., Monroe, J., & Taylor, E. (2014). *Biological science*. Boston: Pearson.

Freeman, S., Eddy, S., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. (2014). Active learning increases student performances in science, engineering, and mathematics. *PNAS. 111* (23).

Freeman, S., O'Conner, E., Parks, J. W., Cunningham, M., Hurley, D., Haak, D., Dirks, C., Wenderoth, M. P. (2007). Prescribed active learning increases performance in introductory biology. *CBE-Life Sciences, 6*, 132-139.

Gardner, D. P., (1983). *A nation at risk: The imperative for educational reform. An open letter to the American people.* Washington, DC: Government Printing Office

Geiger, R.L. (2016). *The history of American higher education: Learning and culture from the founding to World War II.* Princeton University Press.

Gleason, M.A. (1986). Better communication in large classes. *College Teaching. 34*(1).

Goldin, C. Katz, L. (1990). The shaping of higher education: The formative years in the United States, 1890 to 1940. *Journal of Economic Perspectives, 13*,(1). 37–62.

Groh, S. E., Williams, B. A., Allen, D. E., Duch, B. J., Mierson, S. and White, H. B., III (1996) Institutional change in science education: a case study. In *student-active science: Models of innovation in college science teaching.* (McNeal A. P. and D'Avanzo, C. Eds.) Saunders Publishers, Philadelphia, PA.

Handelsman, J., Miller, S., Pfund, C. (2007). *Scientific teaching.* New York: W.H. Freeman and Company.

Haskins, C. (1957). *The rise of universities.* Ithaca: Cornell University Press.

Hayes, W. (2006). *The progressive education movement: Is it still a factor in today's schools*? Rowman & Littlefield Education.

National Research Council. (2003). *BIO2010: Transforming undergraduate education for future research biologists.* National Academies Press.

Novak, J. (1990). *Concept mapping: A useful tool for science education*. Journal of Research in Science Teaching. *27* (10), 937-949.

Robson, D.W. (1985). *Educating republicans*: *The colleges in the era of the American revolution 1750-1800.* Westport, Conn.: Greenwood.

Rosenthal, D.B. (1990). What's past is prologue: Lessons from the history of biology education. *The American Biology Teacher, 52* (3), March 1990.

Rutherford, F.J. (1990). *Science for all Americans*. New York: Oxford University Press.

Rutherford, F.J. (1997) *Sputnik and science education*. American Association for the Advancement of Science. Retrieved from http://www.nationalacademies.org/sputnik/ruther1.htm.

Singer, S. R., Nielsen, N. R., and Schweingruber, H. A. (2017). Biology education research: Lessons and future directions. *CBE—Life Sciences Education. 12*, 129–132.

Treacy, D. J., Sankaran, S. M., Gordon-Messer, S., Saly, D., Miller, R., Isaac, R. S., Kosinski-Collins, M.S. (2011). Implementation of a project-based molecular biology laboratory emphasizing protein structure-function relationships in a large introductory biology laboratory course. *CBE-Life Sciences Education*, *10*, 18-24.

University of Delaware. (2017). *Brand platform style guide*. Retrieved from http://www1.udel.edu/ocm/pdfs/brand-style-guide.pdf

White, H. B. (1996). Dan tries problem-based learning: A case study *To improve the academy, 15*. 75 - 91. Stillwater, OK: New Forums Press and the Professional and Organizational Network in Higher Education.

Appendix I

EXAMPLE SYLLABUS CREATED IN ReLIC INSTITUTE

University of Delaware	BISC208 Introductory Biology II
	Credits: 4, **Section(s):** 013
	Semester: Fall, **Year:** 2018
	Meeting Days, Times, Location and Room: M/W/F, 11am - 12:15pm, Kirkbride 006

1. Instructor Information

Instructor name	Benjamin Rohe, M.S. Ed.D. Candidate
E-mail address	bgroh@udel.edu
Website	http://www1.udel.edu/ctcr/benjamin-g-rohe-ms.html
Office location	241 Wolf Hall
Office hours	Thursday 1-3pm
Phone number	x1291
Special contact instructions	Email is the recommended method of contact. An effort will be made to respond within 48 hours. Students should also expect a response during regular business hours 9-5, this may vary but most will occur within those time frames.
Instructor information	My interests can be rather diverse, but I have a great passion for science education. Apart from teaching various Biology courses, I teach techniques and protocols in cellular and molecular biology through my role as the laboratory manager of the Center for Translational Cancer Research Core Facility.

Teaching Assistant(s)

TA name	
E-mail address	
Office location	
Office hours	

Phone number	

2. Course Description

Pre-requisites

Prereq: BISC207 or BISC 205; Coreq: CHEM104 or CHEM108 or CHEM112.

Description

In this course we will learn the mechanisms of evolution, physiology of multicellular plants and animals, principles of ecology with an emphasis on the biology of populations. The laboratory focuses on testing of hypotheses, data analysis and scientific writing. We will also study the anatomy of animals and plants in both lecture and lab. This course builds on the concepts learned in BISC207 and corresponds with the general education goals of graduates being critical thinkers and clear science communicators.

Course Delivery

This course meets in the face to face format, but will occasionally utilize online quizzes for practice or participation. Out of class assignments are also hosted on the text publishers website and will count towards the course grade.

3. Learning Outcomes

1. Students that accel in this course should be able to correctly implement the scientific method by hypothesizing and executing experiments on plant and animal physiology.

2. They will be able to summarize the effects of evolution by explaining the driving forces behind an organism's anatomy, physiology and behavior.

3. They will also be able to demonstrate the ability to clearly communicate scientific theories and concepts with the general public by dispelling myths and explaining evidence based thinking.

4. Learning Resources

Required Learning Materials

Freeman *Biological Scienc 6/E* Plus MasteringBiology,   ISBN: 97801323509296.

Technology

The syllabus and lectures will be posted using UD's Canvas course management system. Every attempt will be made to post lecture material the day before class. However, this is not always possible.
The course will also utilizer iClicker technology for in class quizzes and polling.
Pearson's MasteringBiology will be used for out of class assignments, purchase can be made in bundles from the bookstore.

Additional Learning Resources

The course is utilizing UDCapture https://udcapture.udel.edu/2018f/bisc208-013/ However this is not a replacement for attending class. Some other recommended resources include the peer tutor and drop in tutoring sessions in ISE lab as well as the Office of Academic Enrichment .

5. Course Assessment

Final Grade Breakdown

The final course grade will be calculated using the following categories:

Course Component	Percentage of Total
Lecture Exams and quizzes	65
Lecture out of class assignments	10
Laboratory overall course grade	25

Assessment Category 1

BISC208 students will take 4 in class exams and several in class clicker quizzes. The 65% determined from this category will be calculated by dividing the students total points scored by the total possible points acquired.

Assessment Category 2

Out of class assignments to be completed on Mastering Biology website. The schedule of events will contain the rough dates the assignments should be completed. A more accurate prescription of assignments can be seen on the masteringbiology.com website linked to this course. *Here I will attach the link to the correct course ID from Pearson.*

Assessment Category 3

The breakdown for the laboratory overall course grade will be described on the laboratory syllabus. Roughly, the grade will be calculated by several worksheets and written assignments as well as a lab final exam. As in lecture, your points score will be divided by the total possible points. This will count for 25% of the overall course grade.

Grading Scale

Students will be assigned the following letter grade based on the calculation coming from the course assessment section.

Grade	Interval		Grade	Interval
A	[[93.50 and over]]		D+	[[66.50 to 69.49]]
A-	[[89.50 to 93.49]]		D	[[62.50 to 66.49]]
B+	[[86.50 to 89.49]]		D-	[[59.50 to 62.49]]
B	[[82.50 to 86.49]]		F	[[Below 59.49]]
B-	[[79.50 to 82.49]]		Z	A "Z" grade is acceptable for a student who never attended or stopped attending a course and
C+	[[76.50 to 79.49]]			

C	[[72.50 to 76.49]]			there is no pre-printed "W" on the roster. Please see the Registrar's website regarding all acceptable grading options for final grades.
C-	[[69.50 to 72.49]]			

6. Course calendar

Date	Theme/Topic	Learning Outcomes Addressed	Assignments Due
8/28	NO CLASS		
8/30	Intro	Syllabus	
9/1	Evidence for Evolution	Outcome 2 evolution Lab outcome 1/2	Lab Exercise 1 SimBio
9/4	NO CLASS		
9/6	Driving forces Evol	Outcome 2 evolution	
9/8	Driving Forces Con't	Outcome 2 evolution Lab outcome 1/2	Lab Exercise 2 Alu insertion Freq. p1
9/11	Speciation	Outcome 2 evolution	
9/13	Speciation	Outcome 2 evolution Lecture exercise outcome 3	Lecture: Define driving forces behind superpowers
9/15	Phylogenies	Outcome 2 evolution Lab outcome 1/2	Lab Exercise 3 Alu insertion Freq. p2
9/18	Phylogenies	Outcome 1 evolution	
9/20	**EXAM I**		
9/22	Intro Plant	Outcome 2 plant anat/phys Lab outcome 1/2	Lab Exercise 4 Transpiration
9/25	Plant Anatomy	Outcome 2 plant anat/phys	
9/27	Transport	Outcome 2 plant anat/phys	
9/29	Transport/Growth	Outcome 2 plant anat/phys Lab outcome 1/2/3	Lab Exercise 5 Transpiration Project Lab Report
10/2	Signaling Hormones	Outcome 2 plant anat/phys	
10/4	Defenses	Outcome 2 plant anat/phys Lecture exercise outcome 3	Lecture: Define the driving forces behind plant coloration

10/6	Defenses	Outcome 2 plant anat/phys Lab outcome 1/2	Lab Exercise 6 Cladograms
10/9	**EXAM II**		
10/11	Intro Animal Phys	Outcome 2 Animal anat/phys	
10/13	Intro cont'	Outcome 2 Animal anat/phys Lab outcome 1/2	Lab exercise 7 Human Respiration
10/16	Respiratory	Outcome 2 Animal anat/phys	
10/18	Respiratory/Circulator y	Outcome 2 Animal anat/phys	
10/20	Circulatory	Outcome 2 Animal anat/phys Lab outcome 1/2/3	Lab exercise 8 Daphnia Circulation Lab Report
10/23	Nervous	Outcome 2 Animal anat/phys	
10/25	Nervous	Outcome 2 Animal anat/phys	
10/27	Nervous	Outcome 2 Animal anat/phys Lab outcome 1/2	Lab Exercise 9 Chordate Dissection
10/30	Innate/adaptive Immune	Outcome 2 Animal anat/phys Lecture exercise outcome 3	Lecture: Define a system of your favorite pokemon/cartoon character
11/1	Immune	Outcome 2 Animal anat/phys	
11/3	Review		
11/6	**EXAM III**	Lab outcome 1/2	Lab Exercise 10 SimBio Ecology
11/8	Intro Ecology	Outcome 2 Ecology	
11/10	Intro cont'	Outcome 2 Ecology	
11/13	Populations/interactio ns	Outcome 2 Ecology Lab outcome 1/2	Review for Lab Final
11/15	Populations/Interactio ns	Outcome 2 Ecology	
11/17	Examples of Pop Eco	Outcome 2 Ecology	
11/20-11/24	**THANKSGIVING**	**BREAK**	
11/27	Ecosystems	Outcome 2 Ecology	**In Lab Final**
11/29	Ecosystems	Outcome 2 Ecology	

12/1	Global	Outcome 2 Ecology	
12/4	Carrying Capacity	Outcome 2 Ecology	
15/6	Conserve Biodiversity	Outcome 2 Ecology	
12/8	Review		

Course Policy Document

Attendance

Attendance in class is strongly recommended. It is the time to clear misunderstandings and answer questions of the material. Quizzes will occasionally be taken by use of iClicker which will also serve as a means for recording attendance. Missed quizzes will not be made-up unless excused absences are provided.

Absences on religious holidays listed in University calendars is recognized as an excused absence. Nevertheless, students are urged to remind the instructor of their intention to be absent on a particular upcoming holiday. Absences on religious holidays not listed in University calendars, as well as absences due to athletic participation or other extracurricular activities in which students are official representatives of the University, shall be recognized as excused absences when the student informs the instructor in writing during the first two weeks of the semester of these planned absences for the semester.

Communication

Communication with the instructor should be done through email. Verbal conversations may only serve as a reminder or informal communications.

Academic Integrity

Please familiarize yourself with UD policies regarding academic dishonesty. To falsify the results of one's research, to steal the words or ideas of another, to cheat on an assignment, to re-submit the same assignment for different classes, or to allow or assist another to commit these acts corrupts the educational process. Students are expected to do their own work and neither give nor receive unauthorized assistance. Complete details of the university's academic integrity policies and procedures can be found at http://www1.udel.edu/studentconduct/policyref.html Office of Student Conduct, 218 Hullihen Hall, (302) 831-2117. E-mail: student-conduct@udel.edu

Harassment and Discrimination

The University of Delaware works to promote an academic and work environment that is free from all forms of discrimination, including harassment. As a member of the community, your rights, resource and responsibilities are reflected in the non-discrimination and sexual misconduct policies. Please familiarize yourself with these policies at http://www.udel.edu/oei . You can report any concerns to the University's Office of Equity & Inclusion, at 305 Hullihen Hall, (302) 831-8063 or you can report anonymously through UD Police (302) 831-2222 or the EthicsPoint Compliance Hotline at http://www1.udel.edu/compliance. You can also report any violation of UD policy on harassment, discrimination, or abuse of any person at this site: http://sites.udel.edu/sexualmisconduct/how-to-report/

Faculty Statement on Disclosures of Instances of Sexual Misconduct

If, at any time during this course, I happen to be made aware that a student may have been the victim of sexual misconduct (including sexual harassment, sexual violence, domestic/dating violence, or stalking), I am obligated to inform the university's Title IX Coordinator. The university needs to know information about such incidents in order to offer resources to victims and to ensure a safe campus environment for everyone. The Title IX Coordinator will decide if the incident should be examined further. If such a situation is disclosed to me in class, in a paper assignment, or in office hours, I promise to protect your privacy--I will not disclose the incident to anyone but the Title IX Coordinator. For more information on Sexual Misconduct policies, where to get help, and how to reporting information, please refer to www.udel.edu/sexualmisconduct. At UD, we provide 24-hour crisis assistance and victim advocacy and counseling. Contact 302-831-1001, UD Helpline 24/7/365, to get in touch with a sexual offense support advocate.

For information on various places you can turn for help,more information on Sexual Misconduct policies, where to get help, and reporting information please refer to http://www.udel.edu/sexualmisconduct

Inclusion of Diverse Learning Needs

Any student who thinks he/she may need an accommodation based on a disability should contact the Office of Disability Support Services (DSS) office as soon as possible. The DSS office is located at 240 Academy Street, Alison Hall Suite 130, Phone: 302-831-4643, fax: 302-831-3261, DSS Website (http://www.udel.edu/DSS/). You may contact DSS at dssoffice@udel.edu

Non-Discrimination

The University of Delaware does not discriminate against any person on the basis of race, color, national origin, sex, gender identity or expression, sexual orientation, genetic information, marital status, disability, religion, age, veteran status or any other characteristic protected by applicable law in its employment, educational programs and activities, admissions policies, and scholarship and loan programs as required by Title IX of the Educational Amendments of 1972, the Americans with Disabilities Act of 1990, Section 504 of the Rehabilitation Act of 1973, Title VII of the Civil Rights Act of 1964, and other applicable statutes and University policies. The University of Delaware also prohibits unlawful harassment including sexual harassment and sexual violence.

For inquiries or complaints related to non-discrimination policies, please contact:
Director, Institutional Equity & Title IX Coordinator- Susan L. Groff, Ed.D. groff@udel.edu, 305 Hullihen Hall Newark, DE 19716 (302) 831-8063

For complaints related to Section 504 of the Rehabilitation Act of 1973 and/or the Americans with Disabilities Act, please contact: Director, Office of Disability Support Services, Anne L. Jannarone, M.Ed., Ed.S. - ajannaro@udel.edu
Alison Hall, Suite 130, Newark, DE 19716 (302) 831-4643 OR contact the U.S. Department of Education - Office for Civil Rights (https://wdcrobcolp01.ed.gov/CFAPPS/OCR/contactus.cfm)

Appendix J

PROPOSAL AND EXAMPLE SYLLABUS CREATED FOR SEPP GRANT FUNDED ETHICS INCLUSION

To: Center for Science, Ethics & Public Policy / RAISE
From: Benjamin G. Rohe, M.S. Ed.D. (Expected 2016)
bgroh@udel.edu, office x1291

Re.: Proposal for inclusion of ethics into BISC425/625 Cancer Biology

BISC425/625 is a course in the department of Biological Sciences offered every spring semester which enrolls roughly 20 upperclassmen and graduate students. The topics previously covered were much more clinical and factual; cancer causing agents, physiology of cancer, and treatment. The topics of quality of life, clinical trial enrollment and research ethics were usually only brought up if the class showed interest in discussion sections. On occasion a grant would be proposed with a focus on quality of life, health and nutrition.

I propose to include five class meetings focused primarily on the ethical decisions made in primary research, genetic testing and its outcomes, the many ethical issues and concerns about clinical trials, and quality of life/hospice care. I plan to offer the information in short presentations using PowerPoint for roughly less than half the class session. The second half of the class session will be instructor or peer led discussion of the topic. Timing of these sessions within the semester is planned for best use of the material to either introduce/discuss the ensuing or preceding guest speaker respectively.

I also plan to be present during many other class meetings (at least 5) when assignments or student presentations on related material is likely to occur. The topic of the ethical decisions made by the students will be touched on during these class sessions. I also plan to attend many guest speaker sessions, where I again could answer any questions of ethical concerns or discussion topics raised during presentations.
For the purposes of logistics, the previous year's syllabus has been attached as well as the newly proposed syllabus with classes in ethics highlighted. The proposed budget for this endeavor is based primarily on my own effort in preparation and presentation of the material. The value reached is based on my current contract value for a three credit course at ½ the responsibility of teaching a course (co-teaching). There for the proposed

cost of adding ethics to this course is $2000.00 (10 class meetings out of 26 total = ~40% of 3 credits @ $1856 per credit = $2141.00 rounding down).

Syllabus BISC 625 Cancer Biology-Spring 2016

Prerequisites: BISC401 and its prerequisites.
One semester of organic chemistry and Physiology would be helpful.
Instructors: Dr. Carlton R. Cooper (CRC)
Office hours: By Appointment only.
Textbook: The Biology of Cancer, by Robert A. Weinberg, Garland Science, 2014.
Primary literature: Bi-Weekly, as assigned by Professors.
Location/Time: Gore 218, M/W 3:35-4:50pm
Sakai: The syllabus and lectures will be posted using UD's Sakai. Every attempt will be made to post lectures the day before class. This is not always possible.

Goals/Objectives: The course will provide coverage of basic through advanced concepts of Cancer Biology through the use of lectures supported by primary literature and grounded by a basic textbook on Cancer. The course design is intended to develop a sufficient coverage/understanding of topics in cancer biology to allow for independent interpretation of the literature and rationale design of forward thinking research proposals in this area.

Schedule: The schedule of lectures contains the major topics to be considered, however the dates may change. Reading assignments are included. Staying ahead in the reading will greatly facilitate comprehension of the material. This course relies upon scientific nomenclature (terms) peculiar to many disciplines since the study of Cancer Biology draws upon Chemistry, Developmental Biology, Virology and Molecular Cell Biology.

Exams, Assignments and Grading: BISC 625 students will be required to submit two written projects, a 10 page review and a Department of Defense (DoD) style grant (10 page proposals) on topics chosen by the students. Prior to grant submission, students will submit a specific aim page, and then a statement of work (i.e., brief description of the research design/methodology). The students will be allowed to resubmit each grant proposal two times after reviewed by the professor. Students will convene peer-review panels to score grants. Review criteria will be supplied for review as well as examples of previously funded and not-funded grants (if possible). Faculty will serve as review panel Administrators. Standard DoD grant review procedures will be supplied with modifications

Students may be required to analyze, summarize and present primary literature on cancer in a group presentation format.

A traditional written exam may not be administered, because the grant proposals and reviews are exams. However, if the professors decide a written exam is warranted, the questions will be posted on Sakai at midnight the night before the exam (which will be determined in the course). Seven questions will be posted and 5 of our choosing will be used for the in class examination. Exams are essay style and will evaluate concept comprehension. Final letter grades will be assigned at the end of the semester based on class averages. The review and grant (which are considered Exams) will constitute 40% of the grade each, and presentations (Including group activities and peer evaluation) will represent 20% of the grade.

Policy: The due dates for the grant submissions are firm! Plan ahead accordingly. You will lose 10% of the final grade for every day past due. The only acceptable excuses include documented protracted serious illness (head colds, for example, are not an adequate excuse), death of a close family member (documented), or protracted absence from the University on Official University business. Short-term illness should be documented by student health and students should communicate the condition via e-mail as soon as possible. Make-up exams must be taken within 7 days after the original exam date without documentations as indicated above. All other make-ups will be scheduled on reading day. Short-term illness is an unacceptable reason for missing the grant submission deadlines. If your excuse is not accepted, you will receive a 0 for that assignment. If you hold an outside job but have registered for the course, it is assumed you can attend all scheduled sessions for the course and complete all assignments.

Syllabus for Cancer Biology for Spring 2015 (M-W)

Feb 8 M (CRC)	Introduction & Perspective on Cancer

Assmnt: Normal histology (10 min/grp): lung, prostate, breast, skin, pancreas, colon
Due 2/10/16

Feb 10 W (CRC) Ch. 1	Pathology (Stage & Grade: Not Just a bicycle race)
Feb 15 M (BR)	**Literature Review: how to dissect a journal article & ethics of citation**
Feb 17 W (CRC, BR)	Review Paper Workshop
Feb 22 M (CRC)	Carcinogenesis I, Overview: Progression, promotion, exposure, dose etc... Ch. 10 & 11
Feb 24 W (CRC)	Carcinogenesis II: Group Presentations-Student research
Feb 29 M (BR)	**Ethics of Genetics, testing, results, privacy, meaning**
Mar 2 W (CRC)	Inflammation 2 Angiogenesis
Mar 7 M (BB)	Cancer Genetics- Dr. Bruce Boman (BB), Director of Cancer Genetics & Stem Cell Biology Program, Helen F. Graham Cancer Center (HFGCC) Pt
Mar 9 W (CRC)	Angiogenesis 2 Metastasis Ch 13
Mar 14 M (BB)	Cancer Stem Cell
Mar 16 W (CRC, BR)	Grant Proposal: Preparation and Grant
Mar 21 M (CW)	Bioinformatics application in Cancer Research, Cathy H. Wu, Ph.D. Edward G. Jefferson Chair of Bioinformatics & Computational Biology Department of Computer & Information Sciences
Mar 23 W (BR)	**Ethics of Clinical Trials: IRB, IACUC, Treatment**
Mar 25 (FRIDAY)	Review Article Due by midnight
Mar 28-Apr3	Spring Break
Apr 4 M (NP)	Conventional Cancer Therapy and Clinical Trials, Dr. Nick Petrelli, Director of the HFGCC and Director of the CTCR.
Apr 6 W (CRC)	Cancer is Fat- the role of exercise and nutrition
April 11 M (Sam N)	The Needles Story: A former Cancer Biology student recalls information learned in class to help his father survival kidney cancer.
April 13 W (BR)	**Quality of Life and ethics of hospice care.**
April 14 Thurs	Grant background & specific aim page due by 6pm
Apr 18 M (CRC, BR)	Meet with Professors

Apr 20 W (SOAM)	Cancer from a Patient view point-Breast Cancer, Michelle Harris and Donna Minor, Sisters on a Mission (SOAM)
Apr 25 M	No Class….Grant First Draft Due.
Apr 27 W (MB)	Cancer induced Pain- what are molecular underpinning- Dr. Mary Boggs-
May 2 M (DC)	Urogenital Cancers-an updated-Dr. David Cozzolino, Urologist, Brandywine Urology
May 4 W (KLVG)	Inflammatory Breast Cancer, Dr. Ken L. Van Golen
May 9 M (CRC, BR)	Peer Review
May 11 W	Work on Grant Revision
May 13 Friday	Grant Proposal due
May 16 M (BR)	**Ethics of Collaboration in Research**
Final Exam TBA (CRC, BR)	Exam in class during scheduled final time.