Statewide Curricular Alignment & Learning Outcomes for Introductory Biology: Using Vision & Change as a Vehicle for Collaboration

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Abstract
Barriers to transfer students include lost credit caused by lack of curricular alignment across institutions of higher learning. This is particularly evident in series courses like introductory biology. We propose to streamline transfer issues using a shared set of course-level learning outcomes (CLOs) developed collaboratively by faculty across multiple institutions. Our biggest challenge was the development of CLOs aligned to Vision and Change and broad enough for large-scale implementation. We present the CLOs generated by the Northwest Biosciences Consortium faculty network along with data on faculty buy-in to using Vision and Change in their curriculum. Additionally, we found an increased familiarity with and use of Vision and Change in curriculum development over time. Finally, we provide information on implementation of CLOs and suggestions of methods for aligning curricula across networks.

Key Words: course-level learning outcomes; CLOs; introductory biology; vision and change.

Introduction

Vertical Articulation
Undergraduate students navigate unique and diverse pathways to completion of undergraduate coursework. An increasing number of students (~40%: Shapiro et al., 2018) articulate between two-year colleges and four-year colleges and universities as transfer students with a two-year degree (e.g., associates of arts or sciences). Additionally, in modern educational systems, more and more students transfer among several different schools (multiple two-year colleges, reverse transfer back from a four-year to a two-year, etc.) to complete degree or postgraduation requirements (Shapiro et al., 2018). At some point, all students move from introductory courses to upper division courses regardless of whether they transfer between institutions or stay at the same institution. This transition between lower division and upper division coursework, identified as “vertical articulation,” impacts all students, regardless of transfer status. When we consider the curricular alignment necessary for these student transitions, we are also mindful of the concerns around the STEM (science, technology, engineering, and mathematics) “leaky pipeline” (Berryman, 1983; Alper, 1993), which indicates that the number of students entering at each transition point exceeds the number moving on to the next transition point.

Lack of Standardized Majors Biology Curriculum
Unlike other STEM introductory sequences, instructors in the discipline of biology have struggled to agree on a standardized curriculum across the nation. This lack of consensus plays out for introductory sequences and, even more largely, across the whole curriculum (Ledbetter & Campbell, 2005; Timmerman et al., 2008; Gregory et al., 2011; Brownell et al., 2014). Biology lacks a single unifying accrediting or reference body for undergraduate degrees, in contrast to other fields (e.g., chemistry [https://www.acs.org/content/acs/en/education/policies/acs-approval-program/guidelines-supplements.html] and engineering [https://www.abet.org]). This lack of consistent curricular expectations is particularly evident in schools that fall outside the national norm of semesters by remaining on the quarter system and in the introductory biology for life science majors (hereafter majors biology), which ranges from one semester to four quarters in length. Our regional Northwest Biosciences Consortium (NWBC) was founded with the support of a five-year National Science Foundation (NSF) Research Coordination Network (RCN) grant to increase implementation of Vision and Change for Undergraduate Education (V&C) (AAAS, 2011) with the hope of streamlining students’ transition from majors biology to upper division biology coursework.
specifically within the Pacific Northwest (broadly defined) at all types of academic institutions. For more details on the formation of the network and lessons learned, see our companion paper (Baumgartner et al., 2021).

The publication of V&C (AAAS, 2011) provided a scaffold for content (core concepts) and skills (core competencies) that all undergraduate biology students should understand and meet by the end of their four-year degree. V&C provides language around which program reviews and articulation agreements can be built to increase the success of all our students. However, the V&C scaffold was focused on the terminal skills and concepts needed for all biologically literate citizens rather than more specifically on full biology degrees or certain coursework. Inspired by the V&C efforts, NWBC applied the V&C structure and practice to emphasize alignment of majors biology coursework for successful vertical articulation. Majors biology functions as a gateway for life science majors to their upper division coursework in a huge array of both basic and applied fields (e.g., premedical professional, agricultural sciences, forestry, biology, biochemistry, molecular biology, ecology, exercise science) and may be the only biology course or sequence taken at a community college. A portion of students enrolled in an introductory biology sequence are not majoring in biology but rather applied fields, and as a result, they may never take another “biology” course in their undergraduate degree pathway. Thus, a larger task for many majors biology courses is to ensure students have the concepts and competencies key to the biological literacy needed in their careers (AAAS, 2011; Uno, 2012).

Two of the main goals of the NWBC were to facilitate curriculum design and student transition, especially from two-year to four-year institutions, and to develop student learning outcomes aligned with V&C concepts and competencies. These two goals evolved over the course of several network meetings that occurred in years three to five of the NSF-RCN grant into a product of course-level learning outcomes (CLOs). For a full description of NWBC activities, we refer the reader to Baumgartner and colleagues (2021) (esp. Figure 1). In this paper, we share the CLOs, the process of developing them in years three and five (Workshops 2 and 4), and self-reported faculty implementation of V&C (AAAS, 2011) in their teaching practices.

### Methods

To develop the CLOs, NWBC brought introductory and upper division biology teaching faculty together and, using V&C as a guide, we crafted a common understanding of the potential discrepancies and similarities within our majors biology curricula. This common understanding became the foundation for a shared set of broad CLOs covering a full year of majors biology. The development of CLOs occurred in three phases: the network building phase, outcome development phase, and final consent phase.

### Phase 1. Network Building

To be able to engage in the development of shared CLOs, in years one and two of the NSF-RCN grant, NWBC first expanded our network with a variety of activities and faculty from across the region to foster community (see Baumgartner et al., 2021). Our network deliberately emerged from a regional PKAL network to include representatives from two-year community colleges, regional comprehensives, private liberal arts colleges, and large R1 institutions across Oregon. Years one and two were focused on internal network formation, group dynamics, and training (as described in Baumgartner et al., 2021). The professional development model that emerged included the use of virtual platforms, interactive sessions at regional meetings, and thematic annual workshops. As an example of how these activities laid the foundation for the development of CLOs, the year three thematic workshop (Workshop 2) emphasized aligning content with module development for majors biology. We asked faculty (53 participants) to use backward design to create or curate modules based on their learning goals for biology majors. In order to build these modules (not presented here), faculty developed six goals for a first-year biology majors curriculum (Table 1).

Additionally, we wanted to reproduce the efforts of Gregory and colleagues (2011) to give faculty “permission” to reduce content breadth in favor of content depth and competencies. We utilized an activity where faculty prioritized broad topics in majors biology based on chapters of a commonly used textbook (Reece et al., 2014). During this activity, groups of four to six faculty were given color-coded strips of paper tagged with content labels. Color coding indicated alignment to V&C core concepts (Figure 1). We

### Table 1. Six learning goals for life science majors in their biology course(s) developed by NWBC faculty \( n = 53 \) for Workshop 2.

| Goals for One Year of Majors Biology |
|--------------------------------------|
| 1. Apply the process of science. |
| 2. Make evidenced-based decisions (quantitative literacy, information literacy, data). |
| 3. Appreciate the biological world, its impact on us, and our impact on it. |
| 4. Relate and connect the molecular and nonmolecular world. |
| 5. Retain enough biology vocabulary to be able to teach yourself. |
| 6. Develop metacognition skills. |

### Figure 1. Example from a prioritization activity in Workshop 1 where faculty groups determine priority biology concepts for retention postgraduation. Strips were color-coded to V&C concepts (AAAS, 2011).
asked faculty to prioritize the content by considering the importance of students’ understanding of the different content two years after graduation. This prioritization activity and the development of broad learning goals for majors biology helped set the stage for the development of CLOs in our final workshop, while establishing the relationships between members of the network.

Phase II. Outcome Development
In the final year of the grant, NWBC hosted Workshop 4, a two-day workshop focused on vertical articulation of curriculum. On the first day of the vertical articulation workshop, we framed the issue of vertical articulation in the state and region by bringing a panel of higher education and transfer experts from around the region to discuss concerns, conflicts, and potential resolutions to current horizontal and vertical transfer issues. The panel was followed by presenting participants with case studies to highlight specific experiences and concerns and to frame the problem space around building professional trust to support our shared students.

On the second day of the vertical articulation workshop, with support from an external facilitator, we used the principles of dynamic governance (Endenburg, 1998) to collaboratively develop a set of CLOs for one year of majors biology (see Figure 2). After providing faculty with a refresher on V&C competencies and concepts (AAAS, 2011), example learning outcomes, and language about how to write learning outcomes (i.e., SMART goals) (Doran, 1981), we organized the ~70 faculty participants into teams of four to six members based on self-reported biological subdiscipline expertise to develop a minimum set of majors biology sequence CLOs using the major intersections of the BioCore Guide (Brownell et al., 2014). For example, one team would be assigned to write outcomes for the cellular and molecular level of organization related to the V&C core concept of evolution, while another would have a cellular and molecular level of organization related to the V&C core concept of transformations of energy and matter. Other teams would cover outcomes for an ecosystem’s level of organization around evolution, or transformations of energy and matter, and so on. We had two additional faculty teams focused on V&C competencies with support from Alexa Clemmons, who was developing the BioSkills Guide (Clemmons et al., 2020).

Prior to the workshop, we had solicited syllabi from every registered faculty member and institution. We collected 46 unique syllabi from 22 different institutions in Oregon and Washington, varying in number from one to three syllabi from each individual institution. From these syllabi, we retrieved and compiled more than 500 unique CLOs across all syllabi and mapped each CLO to V&C concepts and competencies to the best extent possible to create a compiled set of existing CLOs. Each team was given a copy of the compiled set of syllabi CLOs related to their assigned concept/level of organization as a starting point and a copy of the BioCore Guide (Brownell et al., 2014). Teams worked independently for two hours to develop what they would consider an essential set of CLOs for their assigned content/level-of-organization area based on tools previously mentioned in this article. Criteria for learning outcomes were that they were SMART (Doran, 1981) and aligned with V&C (AAAS, 2011) and they supported transfer skills needed for upper division coursework and provided flexibility in application across different institutions. Newly developed CLOs were shared with all other workshop participants and written feedback was given to each writing team to determine what might be missing, unclear, or extraneous. The original teams then reconvened and refined their CLOs based on this feedback. Finally, the full group of ~70 faculty discussed and “consented” to the majority of the CLOs that same day. The full faculty group modified each outcome until agreement was reached. In dynamic governance parlance, consent means that there are no “paramount objections” (which require proposals for alternatives); in this context, consent indicated that CLOs are good enough to try but can be revisited at a later time. We reviewed two-thirds of the created learning outcomes in the allotted time. To be respectful of participant time, we adjourned as scheduled.

Phase III. Final Consent
Since we were unable to complete the consent process at the workshop, the CLOs were compiled and shared with participants via the QUBES site (https://qubeshub.org/community/groups/nwbc) for additional feedback. CLOs were further edited based on feedback,
and a final round of consent to adopt the CLOs was delivered both via Qualtrics and at a regional conference attended by ~15 participants. In total, the CLOs were reviewed and consented to by ~85 faculty members representing 34 institutions.

**Data Collection**

**Faculty Surveys**

We surveyed participants, using either Google forms or Qualtrics, prior to each workshop hosted during Phase I and Phase II and following the final workshop to collect general demographic data and to determine their familiarity with V&C in biology education (AAAS, 2011) and if they used it in their course design. Data was summarized using Qualtrics and MS Excel. Percentages of faculty who responded to each question were compared with a chi-square test.

**Learning Outcomes**

Through our iterative development process, we received input from faculty on the accuracy and importance of each CLO to a majors biology curriculum. The final and revised CLOs appear in Figure 3. Faculty were given at least three opportunities to add or remove concepts from the learning outcomes, and no additions or removals were suggested. The final set of learning outcomes has been built by nearly 95 faculty members from diverse institution types in the Pacific Northwest and iteratively revised a total of four times. For each level of organization or competency, the learning outcomes include three to twelve outcomes considered essential to a year of majors biology.

**Results**

**Faculty Demographics**

Eighty-eight faculty members participated in development of CLOs from all major institution types in the region (Table 2). Representatives from six out of seven four-year public institutions in Oregon, thirteen out of seventeen community colleges in Oregon, and five private four-year institutions were present. Additionally, twelve institutions (both community colleges and four-year institutions) from Washington and other areas in the region were present. Of the participants, 35% had participated in a NWBC workshop previously. The majority (86%) of participants taught majors biology either as their primary course assignment (24%) or in addition to either upper division courses or non-majors biology. Remaining participants (14%) that did not teach majors biology were mainly administrators or advisors.

**Use of Vision & Change in Curriculum Planning**

Faculty reported varying familiarity with V&C prior to each workshop based on pre-workshop surveys. There was higher familiarity and use with faculty that teach the majors biology course (Figure 4). We also saw that there was an increase in familiarity with V&C over time ($x^2 = 46.759, df = 8, p = 1.704 \times 10^2$). Our final workshop participants were the least likely to use it to guide their teaching and had a higher proportion of individuals that had not heard of V&C. However, when asked if “my department uses V&C to help guide our majors biology curriculum” following the final workshop, the majority (86% of participants) said yes.

Learning Outcomes for a Year-Long Introductory Biology for Life Science Majors Sequence

Figure 3. NWBC Learning Outcomes for a year-long introductory biology sequence for life science majors. These outcomes are based on the V&C (AAAS, 2011) and BioCore Guide (Brownell et al., 2014). Learning outcomes are designed to represent the minimum set of outcomes for a year of biology and are divided by biological subdisciplines (molecular/cellular, physiological, and ecology/evolution) as well as competency-based learning outcomes.
over 55% of respondents agreed or strongly agreed with this statement (Figure 5). Additionally, faculty reported that they found the development of CLOs as a group to be a valuable use of their time (35.7% strongly agree, 57.1% agree, and 7.1% neither agree nor disagree).

Discussion

Using the Collaboratively Developed CLOs to Improve Undergraduate Curriculum

Throughout the lifespan of the NWBC network, we were able to build community (Baumgartner et al., 2021) and develop a variety of useful products, including CLOs presented here. We saw greater adoption of the V&C over time (AAAS, 2011). While fewer Workshop 4 participants were familiar with V&C, this may be a function of the greater number of workshop participants who were administrators or responsible for transfer efforts. Additionally, we made an extensive effort to invite and encourage as much institutional representation as possible. In all previous workshops, participants were largely self-selecting. Regardless, we saw that a significant number of faculty were using V&C to guide their curriculum following the vertical articulation workshop. This may be an indication of the success of both the NWBC and other parallel efforts in our region or merely an artifact of time since publication of V&C. Additionally, we viewed this as an opportunity to spread ideas of V&C in a more cohesive manner to faculty, staff, and administrators as a tool to help guide vertical articulation of curricula. We envision at least three major purposes for these CLOs which we will outline: horizontal alignment of majors biology curriculum, vertical articulation of majors biology curriculum, and development of articulation agreements between institutions.

Horizontal Alignment of Majors Biology Curriculum

There are few guidelines for faculty regarding structure of a majors biology course (see Ledbetter & Campbell, 2005; Timmerman et al., 2008; Gregory et al., 2011). These CLOs provide a guiding framework for a year of majors biology curriculum that spans the three levels of organization proposed in the BioCore Guide (Browne, et al., 2014). We realize that there may be additional outcomes added at specific institutions related to programmatic learning outcomes. As it is divided by level of organization, these CLOs are easily adaptable to institutions that choose to leave out certain levels in favor of covering other levels in more depth, as recommended by some (Gregory et al., 2011). Additionally, this set of learning outcomes was developed by faculty as a grassroot, bottom-up effort, not provided by textbook publishers or administrators, and as such it represents the expertise of many invested in teaching majors biology across institution types and with a wide array of student experiences represented. The CLOs do not point to specific examples or prescriptive models, allowing for flexibility that supports variation in approach due to faculty expertise. One of the most valuable aspects of the process was identification of CLOs that were not tied to specific biological models or minutia but were broad enough to work in a variety of contexts and be taught through a variety of examples.

Vertical Articulation of Majors Biology Curriculum

While there is still a lack of alignment of our curriculum broadly across the region, the development and subsequent adoption of the CLOs can start to move our various curricular renditions into closer alignment of majors biology in order to decrease transfer issues. The outcome of such an effort will be more targeted preparation of students who emerge from their majors biology sequences with V&C outcome of such an effort will be more targeted preparation of students who emerge from their majors biology sequences with V&C knowledge and skill sets, and competencies (introductory curriculum) or will come to their classes knowing how to do these things (upper division curriculum).

Table 2. Faculty positions types, institution types, and teaching responsibilities (percentage of workshop participants’ responses to the question, “Do you teach majors biology courses?” Participants could select more than one option, and numbers are out of 102 total responses for 80 respondents. UD = upper division, Intro Bio = majors biology for life science majors.)

| Position                        | % of Participants (n = 88) |
|---------------------------------|----------------------------|
| Assistant/associate/full professor | 29.0%                      |
| Lecturer/instructor             | 38.0%                      |
| Adjunct faculty                 | 6.3%                       |
| Administration                  | 12.6%                      |
| Advisor                         | 7.5%                       |
| State official or other         | 12.6%                      |
| Institution Type                | % of Institutions (n = 88)  |
| Community college               | 41%                        |
| Private liberal arts college    | 16%                        |
| 4-year public R1 or R2          | 43%                        |
| “Do You Teach Major Biology Courses?” | % of Survey Responses (n = 102) |
| Primarily majors biology (+ UD) | 24% (28%)                  |
| Majors + non–majors biology     | 34%                        |
| No majors biology teaching      | 5%                         |
| No teaching assignment          | 9%                         |
Development of Articulation Agreements between Institutions

One major goal that NWBC had in the development of these CLOs is that they could be used to help develop articulation agreements between institutions. If an institution can show that they are using the CLOs in their majors biology courses, in theory, these courses would be aligned with another institution using them. This alignment would streamline the process of relying on reading through syllabi and primarily checking chapter numbers to ensure that courses are aligned with one another. The CLO development workshop was partially observed by representatives from state-level higher education administrators, and it supported subsequent legislator-mandated work to improve transfer pathways for biology majors.

Recommendations for Implementation of CLOs

We present these CLOS as a starting point for developing a unified majors biology curriculum and as a framework from which to have that broader conversation. We acknowledge as stated above that they may need to be adapted and updated over time through trial and error and as the field of biology continues to evolve. These CLOs may not include all the content or competencies that institutions feel should be in their curriculum and do not attempt to account for prerequisites that may be required at various institutions. This is not meant to be the entire curriculum but rather the minimum set of CLOs for one year of majors biology. However, we wanted the CLOs to be broad enough that all introductory biology faculty would feel comfortable designing curriculum to meet the CLOs yet flexible enough for institutional or regional-specific applications to specific biological topics.

We recommend that these CLOs be implemented in a year of majors biology and split appropriately between terms. The V&C competency CLOs may be scaffolded across terms while the content CLOs would need to be divided between different terms based on biological scale of interest. We recommend making connections across different biological scales wherever possible. For example, if one chooses to start with the cellular/molecular scale, they can revisit specific topics (e.g., membrane transport and equilibrium) when discussing homeostasis at the organismal scale or revisit meiosis when teaching evolution and ecology to create a seamless integration of these CLOs across terms. Some units or states may wish to adopt these CLOS immediately to begin to ease their own transfer issues. We encourage using an inclusive process to get buy-in from faculty at multiple institution types and representing varying faculty roles to ensure that all faculty expertise is equally represented.

Future Considerations, Successes & Directions

As with any major curricular undertaking, we are still in the process of implementing the CLOs broadly. One future consideration is that we may want more integration of the competencies into the content learning outcomes. We were intentional about developing a separate set of learning outcomes directly related to the competencies that would span majors biology terms to ensure that all competencies were represented in all courses as an organizing theme. The full product has less integration than perhaps we would like. However, this aligns somewhat with the structure of the Next Generation Science Standards (National Research Council, 2013) that are being implemented broadly across the US at the K–12 level. More specifically, the iterative nature of the integration of the V&C concepts and competencies mirrors the nature of the disciplinary core ideas, crosscutting concepts, and scientific and engineering practices that guide students toward doing and appreciating science rather than simply memorizing facts. A second consideration is the lack of full participation in the “consent” of the final ecological/evolutionary scale and competency learning outcomes by the full group in person. Because we finished these CLOs remotely and asynchronously, it may be that not all faculty were able to engage fully in their second revision. To compensate for this, we did review these outcomes with a secondary group of faculty members at a regional biology education workshop to ensure that they were fully reviewed and consented to by a critical mass of faculty. While one of the advantages of these CLOs relates to alignment, we know that faculty turnover and a lack of knowledge of the CLOs, and of their origin and purpose, can potentially present difficulties for long-term articulation across institutions and for fidelity to the CLOs over time. We feel that adoption of any shared curriculum must be followed by continual revision over time. As such we present these...
CLOs as a living document and will maintain future updates on the QUBES (Donovan et al., 2015) for all to utilize, comment on, and continually improve over time.

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