

A Road Map for Planning Course Transformation Using Learning Objectives

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ABSTRACT

The Vision and Change report called for biology educators to transform undergraduate biology education. The report recommended educators transparently state what students should know and be able to do and create assessments to measure student learning. Using backward design, learning objectives (LOs) can serve as the basis for course transformation. In this essay, we present a roadmap for planning successful course transformations synthesized from the literature. We identified three categories of critical features for successful course transformation. First, establishing a sense of urgency and offering faculty incentives to engage in this time-consuming work creates a needed climate for change. Second, departments are empowered in this process by including key stakeholders, building faculty teams to work collaboratively to identify LOs used to drive pedagogical change, develop assessment strategies, and engage in professional development efforts to support the process. Third, there must be intentional effort to manage resistance and ensure academic freedom and creativity in the classroom. General recommendations as well as areas for further research are discussed.

INTRODUCTION

Vision and Change in Undergraduate Biology Education calls for educators to incorporate student-centered learning to improve biology education (Brewer and Smith, 2011). The report urges instructors to use assessment opportunities to improve learning and use data to inform future instruction. Learning objectives (LOs) are a natural anchor for these efforts. In a backward-designed course, LOs form the basis for developing high-quality formative and summative assessments (Mager, 1997). This process has been described in excellent detail in Wiggins and McTighe's *Understanding by Design* (1999). LOs communicate the purpose of and the claims being made about instruction (Mager, 1997; Rodriguez and Albano, 2017). Once LOs and assessments are established, instructional activities provide opportunities for students to develop skills and apply content knowledge. Aligning assessments and instructional practice with LOs is the essence of backward course design (Fink, 2003) and should serve as the basis of design at every instructional level: class, unit or module, course, and program (Mager, 1997; Rodriguez and Albano, 2017).

The recently published Evidence-Based Teaching Guide on Learning Objectives (EBTG-LOs) provides recommendations based on the literature for instructors to use when creating, revising, and using instructional LOs in their courses (Orr *et al.*, 2022). Instructional learning objectives, abbreviated as "LOs" in this essay, are specific enough to be introduced at the beginning of a class or session to communicate the purpose of the day's instruction, and align with formative and summative assessment items. Work on the EBTG-LOs began with a review of almost 100 articles published in the past 20 years referencing the use and benefits of "learning objectives," "learning goals," and "learning outcomes"—terms often used synonymously in the literature. Many of the articles referenced the value of LOs and/or the use of LOs but offered no evidence in

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support of the assertions and were excluded. As we reviewed this literature and the articles they referenced, we looked for reports documenting the results of evidence-based practices that were predicated on the development and use of LOs. In doing so we found that the reported use and benefits of LOs was, more often than not, associated with course transformation efforts. We defined “course transformation efforts” as those reporting the alignment and/or modification of multiple aspects of a course with LOs in conjunction with incorporation of other evidence-based practices. Both instructors and students are reported to benefit from the use of LOs, resulting in the core organization of the EBTG-LOs citing 36 articles. Recommendations to instructors for how to support use of LOs from this literature review are summarized in an Instructor Checklist.

Many instructors find it challenging to write effective LOs—especially LOs focused on the development of higher-level cognitive skills that students will need to progress through a program of instruction and achieve success in the academic field (Spindler, 2015). The evidence summarized in the EBTG-LOs indicates that instructors emphasize lower-order thinking skills rather than higher-order thinking skills in both their LOs and assessment items (Clemmons *et al.*, 2020; Heil *et al.*, 2023; Momsen *et al.*, 2010).

While this essay focuses on course transformation driven by LOs, faculty may also consider developing program learning outcomes (PLOs) to guide learning at the program and degree level. Faculty can use PLOs to convey intended goals and competencies for students enrolled in a specific degree program, while using LOs to drive course transformation that promotes the student development of the PLOs (Orr *et al.*, 2022). Together, PLOs and course-level LOs can be used for curricular mapping. Curriculum mapping is useful to identify deficits in the program, assess content coverage, evaluate learning opportunities, and develop comprehensive assessment strategies (Plaza *et al.*, 2007). Faculty may refer to Clark and Hsu (2023) for guidance in developing PLOs for supporting student learning and assessment efforts and Clemmons *et al.* (2022) for guidance in curricular mapping LOs to the Vision and Change-aligned BioSkills and BioCore guides (Brownell *et al.*, 2014; Clemmons *et al.*, 2020).

This essay extends our work on the EBTG-LO through an analysis of the 36 articles included in the guide to better understand the success and challenges of LO-driven course transformations. Fifteen of these were recognized to include evidence of a successful course redesign driven by LOs and were further analyzed for recurring themes. We focused on four broad categories to gain insight on these efforts: composition of faculty group, structure/process, decision-making, and resistance and roadblocks (Table 1).

In this essay, we present a roadmap for institutions planning systemic course transformations using LOs. Course transformations are defined in the literature as employing evidence-based principles to revise course structure and instruction to improve student learning (Wieman, 2014). Course transformations are undertaken and reported in the literature for a variety of reasons. These may include the identification of gaps in student learning or skills development, to improve student outcomes or student satisfaction with the course, in response to accreditation requirements, or when faculty find that instruction is not well aligned with the outcomes by which their courses are measured. The success of course transformation efforts depend on establishing a common vision that requires not only on faculty efforts, but also on administrative support, interdepartmental collaboration, faculty development, and industry feedback (Armbruster *et al.*, 2009; Lightner and Benander, 2010; Chasteen *et al.*, 2011; Ezell *et al.*, 2019). We highlight the challenges faced when undergoing a course transformation and present the lessons learned and common roadblocks that are reported in the literature. We found three major categories of critical features that should be recognized by departmental change agents:

1. Creating a climate for change by establishing a sense of urgency and offering faculty incentives to engage in this time-consuming work.
2. Enacting three common process elements associated with course redesign success that enable and engage departments:
 - a. Including key stakeholders,
 - b. Building faculty teams rather than taking a “lone wolf” approach to work collaboratively to identify LOs, develop assessment strategies, and use the LOs to drive pedagogical change, and
 - c. Engaging in professional development (PD) efforts to support the process.
3. Removing obstacles by managing resistance and ensuring support for academic freedom and creativity in the classroom is essential for successful change in course structures.

CREATING A CLIMATE FOR CHANGE

Course transformation, driven by LOs, requires a fundamental change to the way many instructors approach instruction. John Kotter’s 8-Step Change Model describes three main stages that are critical to the success of a change process: 1) creating a climate for change; 2) engaging and enabling the organization; and then finally 3) implementing and sustaining the change (Kotter, 2012; Laig *et al.*, 2021). Stage 1, creating a climate for change, begins with establishing a sense of urgency. The

TABLE 1. Identifying common themes encountered in LO-driven course transformation

Composition of faculty group	Structure/Process	Decision-making	Resistance and roadblocks
• Who was involved and how was that decided? • Who were the key stakeholders? • What were the roles of group members?	• Were LOs developed and then brought to the group or were LOs created de novo by the group?	• How did the faculty group move forward? How did leadership or facilitation work? • How was consensus reached? • What did the process of decision-making look like?	• What types of resistance were faced, for example, from faculty and from external factors/pressures? • How was dissension addressed?

publication of *Vision and Change* (Brewer and Smith, 2011) was a call to action that created, for many, a sense of urgency for change in biology education. The *BioCore Guide* (Brownell *et al.*, 2014) and the *BioSkills Guide* (Clemmons *et al.*, 2020) offer opportunities for action to educators by providing frameworks for this change. Having access to national, consensus introductory biology LOs that prioritize higher-level thinking and development of skills will provide additional opportunity for action, supplying the essential LOs so fundamental to the process of backward design that is necessary for an LO-inspired course transformation (McTighe and Wiggins, 1999).

Here, we summarize two types of incentives common in our literature review: 1) incentives that compel faculty participation by creating a sense of urgency for course transformation; and 2) funding incentives that support the additional work and effort required from faculty. We propose an additional incentive: providing course release or a similar incentive required to recognize and reward the additional effort of course transformation.

The first major incentive that compels faculty participation is the sense of urgency for course transformation. Indeed, one could argue that all course transformation must stem from a place of need. Several of the research studies leveraged a sense of urgency in their efforts. For example, Information Systems (IS) faculty at James Madison University repeatedly noted a discrepancy between IS students' cursory knowledge and new IS professionals' demonstrable skills in action (Ezell *et al.*, 2019). Recognizing this gap, faculty developed measurable LOs to create definable assessment standards. The goal of their work was to enhance IS students' real-world skills. Similarly, anthropologists at a public midwestern university were challenged to evaluate student learning to meet university and state-level learning goals. To meet this need, the faculty worked together to develop LOs useful for measuring student learning across multiple uniquely designed sections of the same class (Ricke *et al.*, 2019). Gaps in student learning and skills development in an E&M I course spurred a team effort to identify student difficulties and employ a new pedagogical approach based on consensus LOs with supporting course materials. A key element of this transformation was to prioritize their assessment efforts so that they would have tools to convince all departmental faculties that the change was worth undertaking (Chasteen *et al.*, 2011). Poor student attitudes evidenced by student disengagement with the course and the course materials as well as unsatisfactory student performance led to course transformation efforts in an introductory biology course (Armbruster *et al.*, 2009). Their efforts led to a student-centered pedagogical approach that made LOs more explicit to students, emphasized more formative assessment, and incorporated active learning to replace a traditional lecture-based approach. The need for course transformation must be clear to incentivize faculty effort and stimulate the change-making process.

In our literature review, we did not observe consistent mechanisms for recognizing and rewarding faculty that engage in these course transformation endeavors. Course transformation requires faculty effort beyond what is typically expected of their teaching responsibilities, so incentives to support this additional faculty effort are needed for systemic course transformation efforts. Incentives are key to gaining faculty buy-in and

driving the change-making process. We found several successful course transformation efforts that leveraged funding to motivate faculty (Armbruster *et al.*, 2009; Chasteen *et al.*, 2011; Ezell *et al.*, 2019). Given the significant time requirement to learn about this process and undertake the process itself, a lack of additional compensation can lead to frustration and resistance (Ricke, 2019).

Consequently, we propose that a third incentive is needed to reward the outcomes of this work. Faculty doing the work of course transformation deserves recognition for their efforts. Administrators and faculty should consider how to use existing institutional mechanisms for recognizing this faculty work and create new mechanisms for recognition if needed. For example, faculty could receive credit and acknowledgment through annual review processes, performance evaluations, and tenure and promotion. These systems must be institutionalized to support and promote faculty work on course transformations. Teaching is rarely evaluated beyond student course evaluations (Gormally *et al.*, 2014; Brickman *et al.*, 2016).

The time for transforming biology education through LO-driven course transformation is now. Supporting faculty to engage in this design process—for example, through release time, teaching support, or long-term ownership of the course—will empower them as agents of this change and will establish a culture that communicates the expectation for participating in this work. Faculty and administrators must thoughtfully consider how to best support pedagogical development, creativity, motivation, time, and documentation of credit where credit is due, to simultaneously make this effort feasible and support systemic, sustainable course transformation effectively.

ENGAGING AND SUPPORTING THE ORGANIZATION IN THE PROCESS OF CHANGE

In reviewing articles summarizing successful course transformations, we identified common denominators of successful change processes that are consistent with Kotter's model for change (Kotter, 2012; Laig *et al.*, 2021). Successful course transformations require ensuring buy-in through forming influential coalitions, developing a shared vision, and communicating that vision (Kotter, 2012) by:

- Including support personnel with essential and complementary skills
- Engaging key stakeholders such as faculty developers, experienced faculty, and industry leaders
- Building faculty consensus by working in teams rather than a "lone wolf" approach; and
- Supporting faculty with PD that provides time, support, and expertise

These shared process elements are described in context below for faculty to consider in the planning and implementation of their own course transformations.

Successful efforts are often characterized by the presence of a facilitator or support person, as the responsibilities of faculty are extensive and leave little time for the additional details and demands of transforming a course. Additionally, support personnel can provide skill sets the faculty may not have that are necessary to successfully facilitate the change. At the University of Colorado, a science teaching fellow was hired with experience in the discipline as well as with education research and

course transformation (Chasteen *et al.*, 2011). The efforts of this individual were reported to be “immensely valuable” in the analysis of student thinking, assessment, and identifying areas where students have difficulty in the course. At Indiana—Purdue University, the importance of having a trained evaluator was emphasized as key to the success of the anthropology course transformation undertaken (Ricke, 2019). This individual acted as project director and provided skills such as communication, organization, and understanding power differentials that are inherent to a tenure-track system. A facilitator or support person should be selected that can provide expertise that faculty may not have and can engage and enable the organization, contributing to the success of the transformation.

In addition to departmental instructors teaching the course being transformed, key stakeholders may include innovative instructors, undergraduates, PD facilitators, and industry experts. The University of Colorado course transformation reports that 10 faculty members met regularly to ensure broad input on the development of course and instructional LOs, manage expectations, and identify problem areas in the course (Chasteen *et al.*, 2011). They recommend the involvement of instructors that teach courses before or after the course being transformed as helpful with vertical alignment within a program and managing faculty expectations. Similarly, the engagement of all faculty (both full- and part-time) that regularly teach the course in question was reported in planning the departmental assessment redesign of course LOs (CLOs) in the anthropology course at Indiana University—Purdue University (Ricke, 2019). Finally, the redesign at James Madison University also identified regional and national industry leaders as key stakeholders in the course transformation process (Ezell *et al.*, 2019). These industry stakeholders identified a gap between the content knowledge gained in class and their demonstrable “real-world” skills. Their expertise was critical to creating assessments of the skill-based LOs being established in the course redesign. In each of these examples, faculty engagement with key stakeholders was critical in identifying and developing the instructional LOs for the redesign.

Building faculty consensus is critical to successful course transformation. Faculty teams report collaborating to transform courses using active learning and aligned assessments which was predicated on defining LOs. Using LOs to identify the goals of course instruction allows instructors to be specific in identifying the content and skills that will focus and guide instruction. Working in teams promotes consensus building and faculty buy-in while sharing the workload of a course transformation. This supports successful change, which requires evaluation, feedback, and revision (Henderson *et al.*, 2011; Borrego and Henderson, 2014). Working in faculty teams also offers faculty opportunities to engage in critical reflection. A team may be as few as two faculty working together, such as is the case with co-teaching. Co-teaching may offer opportunities for faculty involved in the initial course transformation efforts to support and engage additional faculty in their departments by pairing faculty experienced with the new pedagogy with those less experienced (Haag *et al.*, 2022). This approach gives faculty the opportunity to develop their knowledge of the transformed course, collaborate on instruction, and has been demonstrated to offer faculty the benefits of an interactive approach and critical reflection.

We found that successful efforts typically include faculty working collaboratively to make decisions about which instruc-

tional LOs would compromise the course or program. Consensus building requires regular meetings to ensure broad faculty input (Chasteen *et al.*, 2011) and often leaned on using evidence about student learning collected by faculty to develop a shared vision (Chasteen *et al.*, 2011; Ezell *et al.*, 2019; Kiser *et al.*, 2022). For example, to improve student learning in an upper-division physics course, 10 faculty members reviewed the literature, observed student discussion during class, kept field notes about student learning, and looked through their exams (Chasteen *et al.*, 2011). Using insights gained from their review, faculty defined and articulated what students should know and be able to do by the end of the course, developing new LOs. On a broader scale, a group of faculty from diverse institutions collaborated to create and implement shared CLOs to address difficulties students encountered when transferring course credits due to a lack of curricular alignment across institutions (Kiser *et al.*, 2022). On a national level, the Partnership for Undergraduate Life Science Education (PULSE) initiative leverages the power of building faculty consensus by engaging entire biology departments in workshops designed to develop cohesion and consensus as they embark on curriculum changes that reflect evidence-based teaching and learning strategies (<https://pulse-community.org>). Leveraging faculty as experts who collectively document evidence of student learning is key for consensus building. Assessment can be prioritized as a tool to provide feedback on student learning and for collecting evidence of the effectiveness of the course redesign.

PD efforts that focus on backward design and developing clear and measurable LOs provide faculty with focused time, community support, and valuable expertise to plan an effective course redesign (Armbruster *et al.*, 2009; Lightner and Benander, 2010; Ezell *et al.*, 2019; Chmiel *et al.*, 2022). PDs provide opportunities to change faculty conceptions and can promote faculty reflection, which are strategies that promote change (Henderson *et al.*, 2011; Borrego and Henderson, 2014). For example, Lightner and Benander (2010) report using a series of workshops and seminars to illustrate the value of using meaningful LOs to clarify expectations and minimize implicit assumptions. They found that reviewing evidence of improved student outcomes as a result of using LOs was persuasive to faculty in moving from a content-based course design to an LO-based course design. Likewise, the redesign of an introductory biology course required a significant time investment in PD in the planning and implementation process (Armbruster *et al.*, 2009). This time investment included attendance at a week-long National Academies Summer Institutes on Undergraduate Education in Biology workshop (now known as the National Institute of Scientific Teaching workshops) that provided faculty with the tools and training for implementing backward design in their course redesign. Then, faculty engaged in a series of on-campus seminars led by national leaders in science education provided opportunities to discuss and fine tune their course redesign approach. The IS course redesign attributes the participation of a faculty team of seven in a 5-day workshop engaging pedagogy and course design experts to the success of their curriculum change efforts (Ezell *et al.*, 2019). In the least time-intensive approach that we uncovered, Chmiel and colleagues (2022) report the results of engaging faculty in a half-day workshop to use LOs in the context of backward design to create assessments. Faculty reported collaboration as a valuable element of the workshop and overwhelmingly reported

increased confidence in designing accurate assessments of student learning. In most cases, PD efforts required sustained time investment of faculty rather than one-time engagement.

Reports of successful course redesign describe the time required for planning, executing, and assessing the redesign effort as 1 to 3 years. This is consistent with the finding that effective change strategies for promoting change in instructional practices take place over time (Henderson *et al.*, 2011). Chasteen *et al.* (2011) report that the process of transforming a course requires a minimum of two semesters, with an additional term allotted to planning. Armbruster *et al.* (2009) report their course redesign was a 3-year effort that began with 6 months of preparation. They note that significantly more effort was required during the first semester of implementation versus later semesters. The time investment in this redesign, however, had a positive impact on instructor evaluation criteria and improved instructor morale/enthusiasm. Interestingly, improvement in student attitudes was observed the year before an increase in student performance. This team hypothesizes that faculty experience in implementation is required before improvement in performance is observed (Armbruster *et al.*, 2009).

ONE EXAMPLE OF SUCCESSFUL TRANSFORMATION PROCESS

The redesign of the each of the core courses of the interdisciplinary IS curriculum at James Madison University is one example of a successful effort that applied these common change

processes (Table 2). This team recognized the need for their LO-based course transformation by identifying a need to improve their students' real-world skills (Ezell *et al.*, 2019). This created a climate for change, as the faculty recognized an urgent need for change in each course structure. They enacted the three common process elements we have identified as being associated with course redesign success by engaging key stakeholders, working as a faculty team, and engaging in PD efforts to support their efforts. They began their multi-year course redesign with extensive efforts to identify the successful, real-world IS skills requirements their students need as professionals and revised and created new LOs for all of the courses in their program to improve student outcomes. Assessment rubrics were created over a summer to evaluate their success. After the first year of implementation, the team used their assessment to refine their criteria rubric items as well as to adjust LOs and activities. Reflecting on the success of their course transformation, this team emphasized the need for establishing a common vision to create buy-in and remove the obstacle of faculty resistance to change. Assessment also played an important role in managing resistance, as it provided evidence of improved student skills as a result of the transformation efforts.

REMOVING OBSTACLES BY MANAGING RESISTANCE

A critical step toward engaging and empowering the organization is to check for barriers and remove obstacles (Kotter, 2012, Laig *et al.*, 2021). We found that successful course

TABLE 2. An example course transformation process from James Madison University's IS curriculum (Ezell *et al.*, 2019)

Category of features critical for success	Success elements reported
1. Creating a climate for change	Identified a need to improve students' real-world skills
2. Enacting common process elements to enable and engage departments a. Including key stakeholders	Identified critical skills by reviewing literature and consulting practitioners in the field
2. Enacting common process elements to enable and engage departments b. Building faculty teams to work collaboratively to identify LOs, develop assessment strategies, and use the LOs to drive pedagogical change	Building faculty teams and managing resistance—worked as a faculty team to establish common vision
3. Removing obstacles by managing resistance	Created assessment rubrics to establish criteria to measure baseline and improvement
2. Enacting common process elements to enable and engage departments c. Engaging in PD efforts to support the process	Engaged in 5-day PD workshop led by course design expert to ensure changes aligned with evidence-based practices
2. Enacting common process elements to enable and engage departments b. building faculty teams to work collaboratively to identify LOs, develop assessment strategies, and use the LOs to drive pedagogical change	Evaluated rubric criteria with Bloom's Taxonomy
2. Enacting common process elements to enable and engage departments b. building faculty teams to work collaboratively to identify LOs, develop assessment strategies, and use the LOs to drive pedagogical change	Developed measurable LOs for each course in their core curriculum that developed and supported the needed skills
2. Enacting common process elements to enable and engage departments b. building faculty teams to work collaboratively to identify LOs, develop assessment strategies, and use the LOs to drive pedagogical change	Mapped LOs to the IS curriculum to identify gaps and ensure course alignment
2. Enacting common process elements to enable and engage departments b. building faculty teams to work collaboratively to identify LOs, develop assessment strategies, and use the LOs to drive pedagogical change	Developed a scaffolding map to guide instructors in revising or creating class activities aligned to the new LOs
2. Enacting common process elements to enable and engage departments b. Building faculty teams to work collaboratively to identify LOs, develop assessment strategies, and use the LOs to drive pedagogical change	Assessed students' baseline skills prior to implementation of curricular redesign
3. Removing obstacles by managing resistance	Reassessment of students' skills following curriculum changes to establish evidence of course transformation success

TABLE 3. Strategies to mitigate specific types of faculty resistance to using LOs

Faculty resistance to LOs	Mitigation strategy	Reference
"Spoon-feeds" students	Share evidence of student difficulties. Make implicit assumptions about expectations for learning versus improved student outcomes. Use LOs to clarify expectations for student learning and assessments	Lightner and Benander, 2010
Restricts academic freedom	Clarify that using LOs does not specify how instructors teach, including activities, assignments, and assessments. Faculty should have the freedom to craft their course activities with original LOs	Chasteen <i>et al.</i> , 2011; Hennessey and Freeman, 2024
Administrative burden	Collaboration toward consensus LOs; allowing faculty choice in some percentage of the identified LOs (25% of LOs is suggested by Chasteen <i>et al.</i> , 2011)	Lightner and Benander, 2010; Chasteen <i>et al.</i> , 2011; Dobbins <i>et al.</i> , 2016; Richlin and Cox, 2004; Ricke <i>et al.</i> , 2019

transformations involve recognizing and managing the barrier of faculty resistance to change, especially to using LOs. Faculty resistance to LOs can stem from a myriad of concerns. These concerns include faculty viewing LO as "spoon-feeding" students, inhibiting academic freedom, and perceiving LOs being an administrative "box" to check (Lightner and Benander, 2010). PD efforts that present faculty with evidence of the effectiveness of using LOs can reduce this resistance (Table 3). As a rule, engaging faculty in the benefits of using LOs to structure their assessments and teaching activities to promote learning is reported as critical in minimizing the perception of "administrative busywork" (Richlin and Cox, 2004; Lightner and Benander, 2010; Dobbins *et al.*, 2016). Faculty may adopt a dialectic attitude toward LOs. A survey of English, biology, and medicine faculty found that despite being viewed as fulfilling an administrative requirement, LOs are regarded as useful for structuring courses and programs, helpful in designing assessments, and serve as a helpful learning tool to students (Dobbins *et al.*, 2016).

We encourage incorporating strategies to support faculty creativity and freedom in classroom teaching to aid in managing resistance stemming from concerns about academic freedom. While the goal of course transformation is to promote the use of consensus LOs to unify and improve introductory biology, room for individual innovation is key. One strategy to support individual faculty creativity is collaborative aggregation of individual instructor LOs (Ricke, 2019). The anthropology faculty at Indiana University—Purdue University collectively agreed upon LOs and corresponding assignments that aligned with departmental, university, and state LOs. Faculty committed to including these consensus LOs in their course while maintaining the freedom to include additional LOs that they felt were important. Faculty that used consensus LOs were still able to design their own class activities and assignments. Similarly, the redesign of a junior-level physics course recognized the need for faculty to retain creativity and have flexibility in their teaching (Chasteen *et al.*, 2011). This was accomplished by asking faculty to come to a consensus on 75% of the CLOs and allowing faculty to determine the remaining 25%.

QUESTIONS FOR FURTHER RESEARCH

Course redesign using LOs to improve undergraduate biology education is complex and institution dependent. However, the literature provides evidence of common denominators associated with success that align with Kotter's 8-Step Change Model and can provide a roadmap for faculty embarking on this jour-

ney. Recognizing the urgent need for improving undergraduate biology education and providing faculty incentives to engage in change creates a climate for change. We can apply the key process elements of success identified for this process by recognizing the importance of faculty teams and engaging key stakeholders to develop, use, and assess common LOs to drive the process. Finally, removing obstacles by managing resistance to the change in course structure should be recognized as critical for successful course transformations. Even with these general recommendations in mind, a number of unanswered questions remain that could help support the implementation of LOs to drive course redesign:

Does Student Achievement Improve due to LO-driven Course Redesign, and What Measures are Most Useful to Document Success?

There are few studies in which researchers measured the impact of using LOs to drive course redesign on a single variable, such as student performance on exams (Jalloh *et al.*, 2019). The effect of LOs on student learning is almost necessarily conflated with approaches to assessment and classroom practices, given the role backward design in LO-driven course redesign. However, the question how LO-driven courses affect student achievement—without concurrent changes in instructional methods and assessment—remains. Historical comparisons of student success in sections taught by an instructor "before" and "after" implementing an LO-driven course redesign could provide insight into this question. Determining what defines "success" is another important question that may vary among institutions. Exam scores and student success in the course (Armbruster *et al.*, 2009; Chasteen *et al.*, 2011; Minbiole, 2016; Jalloh *et al.*, 2019), persistence in the program (McGill *et al.*, 2019), and success in the academic field (Ezell *et al.*, 2019) are all parameters identified as measurements of success in our literature review. Additional insight can be gained by interviewing faculty, students, and industry leaders to measure satisfaction with the course and course outcomes. Finally, high-structured courses have been shown to benefit both disadvantaged and advantaged students (Haak *et al.*, 2011). The structure that is derived from an LO-driven course may provide similar benefits and should be examined to determine potential benefits to these groups within the student population.

Which Methods Are Most Effective in Supporting Faculty to Use Consensus LOs to Reform their Courses?

The studies reviewed above described the process of guiding and motivating faculty in building and using consensus LOs to

reform their courses. However, further research can explicitly compare which methods best encourage and support faculty teams to implement already-established consensus LOs for systemic program change. One approach to supporting faculty teams to effect change through PD has been leveraged by PULSE fellows (DeMarais *et al.*, 2021). PULSE fellows acknowledge that faculty teams influence departmental curricula and pedagogies more than individual instructors. With this in mind, PULSE conducts workshops using a systems thinking approach to equip faculty with the skills and knowledge to effect change within their department and organization. A parallel approach could be used to support faculty in creating and using consensus LOs to reform their courses.

How do Faculty Weigh the Inclusion of Skill-based versus Content-based LOs?

The BioSkills Guide, a set of measurable programmatic LOs from Vision and Change core competencies, was developed to guide instructors in helping students gain transferable skills needed to succeed in the modern workforce (Clemmons *et al.*, 2020). Incorporating these skills remains an issue, however. A study of 33 biology courses at one institution reported that the inclusion of skill-based LOs aligned with Vision and Change core competencies was inconsistent, finding that skills such as modeling, doing research, ethics, and interdisciplinary problem solving were underrepresented (Donovan *et al.*, 2022). Further, the skill-based LOs and assessment items that are included tend to require only lower-level thinking skills (Clemmons *et al.*, 2020; Heil *et al.*, 2023; Momsen *et al.*, 2010). We recommend that faculty engage in curriculum mapping efforts to identify areas where intentional inclusion of BioSkills can be enhanced. Tools like the Three-Dimensional Learning Assessment Protocol (3-D LAP) train faculty to write assessments aligned to science and engineering practices that emphasize what students should be able to do with their content knowledge and require higher-level thinking skills (Laverty *et al.*, 2016). Recent work funded by Howard Hughes Medical Institute at Emory also focused on the need for skills to guide a complete redesign of a new 4-year undergraduate chemistry curriculum called Chemistry Unbound (McGill *et al.*, 2019). This effort began with faculty articulating goals that prioritized critical scientific skills. To ensure that these skills were included throughout the curriculum, faculty created instructional LOs focused on core content and scientific skills, and vertically aligned the LOs throughout the curriculum. Assessment of how students engaged in these practices included use of the 3-D LAP protocol.

Is the Use of LOs to Align and Design Assessments and Course Activities Sufficient to Increase Student Learning and Improve Student Outcomes, or Are Active Learning Pedagogies a Pedagogical Requirement for Success?

The literature provides clear evidence that changes in instructional methods generally accompany course redesign (Armbruster *et al.*, 2009; Minbiole, 2016; Reynolds and Kearnes, 2017; Hebert and O'Donnell, 2020; McGill *et al.*, 2019). The observation that active learning supports increased student success is well recognized (Freeman *et al.*, 2014). However, it is unclear whether active learning is critical to the success of an LO-driven course. Changes in instructional methods to include active learning are reported as a key component of success

(Armbruster *et al.*, 2009; Minbiole, 2016; Reynolds and Kearnes, 2017; McGill *et al.*, 2019; Hebert and O'Donnell, 2020), but the retention of standard lecture practice was also reported in successful course redesign (Chasteen *et al.*, 2009). Thus, questions remain as to whether active learning is critical to successful course redesign.

Assessing the potential requirement of active learning pedagogies accompanying LO implementation might be done by capitalizing on a documented course redesign challenge where implementation strategies differ among departmental faculty (McGill *et al.*, 2019). Coding faculty according to the implementation of the various aspects of the redesign plan could allow identification of key differences in success that correlate to those aspects of implementation. Another option would be to capitalize on multi-section courses to compare lecture-based sections versus sections utilizing active learning. Alternatively, it may be beneficial to implement change incrementally, assessing changes in student achievement along the way. Rolling out the redesign plan by prioritizing the consensus LOs and creating two-three shared assessments, would allow faculty freedom in their teaching approach. Assessment outcomes could be measured and compared with these teaching approaches, and this evidence could guide faculty to make informed decisions about future teaching approaches. This approach raises red flags, however, as “freedom” to employ teaching approaches not consistent with evidence-based teaching practice calls the question of ethics and responsibility toward students (Freeman *et al.*, 2014).

How Can We Best Teach Students to Utilize LOs for their Learning, and do LOs Lead to Increased Gains in Metacognition, Study Strategies, and/or Reduced Time on Task?

Teaching students to use LOs to increase the transparency of course objectives and assessment topics may also further the impact of LOs to improve student learning outcomes, beyond instructor use for backward course design (Simon and Taylor, 2009; Brooks *et al.*, 2014; Osueke *et al.*, 2018). The consideration of students leveraging LOs to improve their success raises several important yet unanswered questions about the use of LOs.

- How can instructors help students better understand the performance, conditions, and criteria required by the LOs to demonstrate successful learning?
- Are there best practices for instructors to motivate students to learn to use LOs in self-assessment strategies? Using LOs to drive the “pretesting effect” (Beckman, 2008; Sana *et al.*, 2020) gives us some insight. It is not clear how broadly applicable—in terms of discipline and course setting—the benefit of converting LOs to pretest questions—questions that students can use to guide their studying—might be to students.
- Will teaching students to use LOs differ for learners at different institutions, where the academic preparedness and/or readiness level may vary greatly? Does explicit use of LOs support broadening participation in STEM for students from marginalized populations?

This essay reviews the defining features of successful LO-driven curricular redesign to provide an excellent roadmap for campus leaders to support individual efforts. Now is

the time for educational researchers to grasp the baton to investigate these nuanced questions in larger multi-institution investigations.

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