Triadic alignment is a pedagogical technique that instructors can use to improve their teaching and students’ learning. It involves offering the course learning objectives, teaching and learning activities, and assessments at the same cognitive process level. Though it represents a best practice, few instructors have assessed the efficacy of triadic alignment. Previous research has demonstrated that General Biology courses are commonly misaligned relative to the objectives and assessments. However, little emphasis has been placed on assessing the teaching and learning activities as the third component of triadic alignment. In this article, we describe how a General Biology course was initially misaligned, the process that was taken to align it, and the improved student outcomes that resulted from triadic alignment. We expand our discussion to include types of misalignment and the benefits of triadic alignment for both the students and the faculty member.

INTRODUCTION

New college and university faculty members with Ph.D. degrees have extensive research training but often lack a similar level of pedagogical training (1, 2) and therefore have limited knowledge of the teaching and learning literature and current best practices (3–5). Understanding Anderson et al.’s cognitive process dimensions can facilitate the transition to a teaching-intensive faculty position (6). These dimensions, or levels, are defined as remember, understand, apply, analyze, evaluate, and create (6). These pedagogical levels can be used to categorize learning objectives, teaching and learning activities (TLA), and assessments (including exam questions). Large introductory college lecture courses emphasize remember and understand levels, but these courses should also build students’ higher-level thinking skills (7–10).

First-year college students have experience with learning at the remember and understand levels (lower-level thinking), but they may not know how to engage in higher-level thinking skills including applying knowledge to novel situations, analyzing data, evaluating situations, and creating original work. Because the students have not had as much experience with the course material and are still developing higher-level thinking skills, they may need explicit guidance to work effectively at the apply, analyze, evaluate, or create cognitive levels. In contrast, new faculty members were recently engaged in these higher-level thinking skills while writing their own research papers, and the skills therefore come naturally. It can be challenging for a novice teacher to remember what it was like to learn new material for the first time.

Due to time limitations associated with developing and assessing teaching and learning strategies (2, 11), new faculty often rely on lecturing to deliver course content and disseminate knowledge (12). Lecturing is a traditional model that is familiar to new instructors because that may be the way they were taught. However, lecturing only passively involves the student in the learning process and does so at the lower cognitive skill levels of remember and understand (13, 14). The pedagogical literature emphasizes the need for active engagement in course material to promote deep learning at higher cognitive levels (2, 7–9, 12, 13, 15–18). Active learning exercises give students the opportunity to apply conceptual knowledge to novel and relevant situations, which can ultimately improve student learning (12, 14, 16, 17, 19). A lack of active engagement hampers students’ ability to deeply learn the material, and they may not perform well on exams that test at the apply level or above. Students become frustrated when they are tested at a higher level than what they have practiced in class. Poor student performance can, in turn, lead new instructors to become frustrated, as the students are not meeting their expectations. This disparity between the students’ and instructors’ expectations and performance can even lead to poor evaluations of the instructor by the students, further frustrating the new teacher (16).
APPLYING CONSTRUCTIVE OR TRIADIC ALIGNMENT

One way to effectively incorporate active learning and practice higher-level thinking skills is to use the pedagogical technique of integrated course design (13, 14, 20) or constructive alignment (15, 21). These methods integrate three aspects of a course: 1) learning objectives; 2) TLA; and 3) assessment of student learning (13–15, 20, 21). This integration requires that three course components be aligned at the same cognitive level (13–15, 20, 21) and ensures coherence between instructor expectations, content delivery, and assessment of students (19). When one of these components is not at the same cognitive level as the others, the result is course misalignment.

TYPES OF MISALIGNMENT

Courses can be misaligned in different ways (see Table 1). One type of misalignment occurs when course objectives include higher cognitive levels (analyze, evaluate, or create), but students are assessed with multiple-choice exams where they are not required to demonstrate higher-level skills (13, 19, 22, 23). This frequently occurs in large classes where it is difficult to efficiently grade essay-type assessments (10) and represents the most common type of misalignment (23). Momsen et al. (10) assessed pedagogical congruency between course goals and examination questions in Introductory Biology courses across the United States. Of the stated goals, 69% were classified as the remember/understand (R/U) levels, yet 93% of the quiz and exam questions (“high-stakes assessments”) were at the R/U levels. Since 31% of the goals were at higher cognitive levels but only 7% of the exam questions were asked at these levels, it is clear that the assessments were not aligned with the goals. These data indicate that misalignment is a widespread problem in Introductory Biology courses taught in the United States.

Misalignment also occurs if only lower-level (R/U) skills are stated as course objectives but higher-level skills (apply, analyze, evaluate) are assessed without students having had an opportunity to practice them (13, 14). New faculty members may experience this type of misalignment if they focus on content delivery and neglect to model for students how to engage in higher cognitive level skills. When courses are misaligned in this manner, students can perform poorly on assessments (13, 24).

Data from Momsen et al. (10) and O’Neill et al. (24) illustrate the importance of connecting learning objectives with assessments. It is relatively easy to use Bloom’s taxonomy (25) to categorize the learning objectives and assessments to determine a quantitative alignment score between the two. A critical component of triadic alignment, however, includes TLA that are at the same cognitive level as the learning objective(s) and assessments for that skill. If students are not guided on how to engage in higher-order skills or provided opportunities to practice these skills, they may perform poorly on assessments and examinations (16).

Without in-class activities, students are not always able to gain higher cognitive skills (22). If higher-level thinking is a desired course objective, then it is important for students to both have opportunities to practice the specific skills inside and/or outside of class and to be assessed at the higher levels. Fully implementing course alignment by connecting learning objectives, TLA, and assessments ensures consistency within the course (19) and can improve student learning and attitudes about the course and enhance instructor confidence.

CASE STUDY

After her first year teaching General Biology I, a new faculty member reflected on ways in which she could improve her course. Exam averages were lower than she expected and the students commented that the exams were much too challenging. Discussion with other faculty members initially led the new faculty member to recognize that her expectation of the students’ ability to answer apply/analyze/evaluate (A/A/E) questions on exams was too high for an introductory course. The new faculty member had recently completed postdoctoral training in a research-intensive laboratory and was engaged in higher-order thinking on a daily basis. In contrast, the first- and second-year undergraduate students in her class were not proficient at taking information from the lecture notes and textbook and applying it to novel situations. The instructor eventually realized that the application of information was a relatively easy skill for her but seemed to be an unattainable task for the students, particularly without any modeling of the skill for the students. Too many questions at the A/A/E levels were asked on the first two exams during her first year of teaching, which was not consistent with the R/U learning objectives of the course during that year (Supplemental Fig. 1). The instructor reduced the number of A/A/E questions on exams 3 and 4 during the first year and in all exams during the second and third years of her teaching, allowing for partial alignment. Despite the changes to the later exams during the first year, students’ exam scores (Fig. 1) and attitudes about the course (Figs. 2 and 3) were still disappointing. More changes were necessary to improve students’ performance and attitudes.

After conferring with her mentor and the Director of the Teaching and Learning Center, the new faculty member realized her course was still misaligned. Even though learning objectives and exam questions were revised to be at the same cognitive level, they were not being supported by TLA at the apply level. Students did not practice higher-level skills in class, and this may have contributed to their continued poor performance on exams. This prompted the new faculty member to reflect on how she was teaching the class. In year 1, most of her preparation time was spent constructing Powerpoint slides with the content in bulleted form. During class, the instructor predominantly lectured (> 90% of the time) by revealing the bullets and mainly reiterated the content on the slides. Real-world examples of
the concepts were provided within the Powerpoint slides, but the students did not appear to form concrete linkages between the concepts and examples. Questions were infrequently asked and the students did not discuss the content with one another during class. The main emphasis was on the instructor delivering a large amount of content rather than on the depth and quality of content covered. Students did little to engage with the material during the lecture, thus representing a teacher-centered approach. The new instructor recognized that in order to improve student learning, she had to provide more activities that required students to think about the material and process information on their own.

Importantly, new TLA at the apply level were added in years 2 and 3 to achieve alignment between specific course objectives, TLA, and course assessments. These included in-class activities and exam question modeling sessions. For example, three activities included: 1) a case study to engage the students in the scientific method; 2) a demonstration of how a buffer functions; and 3) modeling mitosis and meiosis using pipe cleaners. These activities involved students working together in groups to answer specific questions related to a biological concept. Other learning opportunities that students rated positively on course evaluations were practice exam question modeling sessions. Multiple-choice questions at the apply cognitive dimension were given to

| Misalignment Type 1: Common with large lecture-style courses | Cognitive Process Level |
|-------------------------------------------------------------|-------------------------|
| Learning Objectives                                         | ✓ ✓ ✓ ✓ ✓ |
| Teaching and Learning Methods                               | ✓ ✓ ✓ ✓ ✓ |
| Assessments (including exam questions)                      | ✓ ✓ ✓ ✓ ✓ |

| Misalignment Type 2: Common with novice faculty             | Cognitive Process Level |
|-------------------------------------------------------------|-------------------------|
| Learning Objectives                                         | ✓ ✓ ✓ ✓ ✓ |
| Teaching and Learning Methods                               | ✓ ✓ ✓ ✓ ✓ |
| Assessments (including exam questions)                      | ✓ ✓ ✓ ✓ ✓ |

| Aligned course                                              | Cognitive Process Level |
|-------------------------------------------------------------|-------------------------|
| Learning Objectives                                         | ✓ ✓ ✓ ✓ ✓ |
| Teaching and Learning Methods                               | ✓ ✓ ✓ ✓ ✓ |
| Assessments (including exam questions)                      | ✓ ✓ ✓ ✓ ✓ |

| TABLE 1. Triadic course mis(alignment).                      |

This table illustrates two ways in which courses can be misaligned. If checkboxes are not vertically aligned, it indicates the course is misaligned. The bottom chart illustrates triadic course alignment in an introductory Biology course where all three course components are offered with similar cognitive process levels.
students via clickers as formative ungraded assessments the week before each exam. Students answered these questions anonymously to ascertain whether they could apply their knowledge to novel situations. This helped students determine whether they knew the material one week prior to the exam and also allowed them to practice answering higher-level thinking questions. Immediately after the question was asked, the faculty member modeled the reasoning and logic for how the incorrect answer choices could be eliminated and why the correct answer was the best choice. As the semester progressed, students modeled to each other which choices were incorrect and which one was the most correct choice using peer teaching. Therefore, as the course progressed, students took greater responsibility for their learning during these sessions and relied less heavily on the instructor providing the answers. Thus, a major change the new instructor made to the course in years 2 and 3 of her teaching was changing how content was covered during class time in order to get the students more actively engaged in the learning process.

Only when the TLA changed did the new instructor see students' performance on exams significantly increase in years 2 and 3 of her teaching compared with year 1 (Fig. 1; IRB approval 610678-I). Students' attitudes about the course also changed significantly, indicating they felt they learned more, and that the course content related to material on the exams (Fig. 2). Interestingly, as the students' perception of alignment improved, their perception of how much they learned also improved (Fig. 3). This suggests that triadic alignment positively impacts student perceptions of learning. Because the students were doing better on the exams (Fig. 1) and seemed to enjoy the course more, the faculty member's confidence and enjoyment in teaching also improved.

DISCUSSION

Crowe et al. (16) point out that students can perform poorly on exams if they have not been provided adequate opportunities to practice higher-level objectives, which is what happened with the new faculty member in her first year of teaching. Just as one would not expect a novice driver to pass a driver's test without practice, faculty members should not expect their students to pass assessments without adequate practice of the corresponding learning objectives. Crowe et al. and Porter et al. (16, 26) provide excellent examples of courses that utilized alignment and demonstrated the importance of modeling or giving students the opportunity to practice higher-order skills prior to assessments. This demonstrates the importance of TLA.

**FIGURE 1.** The average exam scores over three successive years of a new instructor's teaching. Data were analyzed by one-way ANOVA comparing exam scores in years 1, 2, and 3. Individual exams were then compared with one another using post-hoc Bonferroni's t-tests. Statistical comparisons are displayed within the exam number across years. "Overall" represents the mean of all exams within a particular year. Within the exam number, bars with different superscripts are statistically different from one another (p < 0.05). N = 109, 80, and 67 for Years 1, 2, and 3, respectively.

**FIGURE 2.** Students' responses to the end-of-semester evaluation statement "Exams and assignments related to course content" in three successive years. A Cochran-Mantel-Haenszel test was performed to determine whether the distribution of students' attitude responses differed between the three years. Bars with different superscripts are statistically different (p < 0.05) from one another.

**FIGURE 3.** Students' responses to the end-of-semester evaluation statement "Learned a lot from this course" in three successive years. A Cochran-Mantel-Haenszel test was performed to determine whether the distribution of students' attitude responses differed between the three years. Bars with different superscripts are statistically different (p < 0.05) from one another. (Data provided from the evaluation system were rounded to the nearest whole number; therefore, not all sums total 100%.)
in achieving triadic alignment, making it clear that simply aligning learning objectives with assessments is not enough.

Although triadic alignment is a sound pedagogical principle, there are relatively few rigorous assessments of it. Jensen et al. (27) purposefully misaligned a course to assess triadic alignment. The group of students whose course was fully aligned at a higher cognitive level performed better on the final exam than those students whose course was misaligned. Other researchers reported that students enrolled in courses where learning objectives, TLA, and assessments were all aligned were more likely to engage in deep learning compared with their peers in misaligned courses (28). While previous studies have assessed alignment of objectives with assessments, our study reports on the impact of triadic alignment on knowledge improvement. Additionally, we report on the positive impact of triadic alignment on students’ perception of learning.

These data support the idea that course alignment involving all three components is essential for students’ development and competent use of higher-level cognitive skills. Given that misalignment is common in introductory biology courses across the United States (10), greater use of triadic alignment is warranted. If triadic alignment is as effective as we believe it to be, teaching and learning centers should train instructors on how to incorporate triadic alignment into their courses. Even if teaching and learning centers help to disseminate the technique more widely, it requires that the teacher have adequate time to reflect on each of the three aspects of a course: the learning objectives, the specific teaching and learning methods for each learning objective, and the assessments. If faculty are provided additional developmental time to reflect on, revise, and improve their courses, they will more successfully integrate triadic alignment into their courses. Triadic alignment is relatively simple to implement with appropriate training and time and provides positive benefits for both students and faculty.

SUPPLEMENTAL MATERIALS

Appendix 1: Cognitive process level analysis of exam questions.

ACKNOWLEDGMENTS

The authors thank Dr. Laura Pontiggia, Professor of Math, Physics, and Statistics, for her guidance on the statistical analyses. The authors also thank Dr. Phyllis Blumberg, director of the Teaching and Learning Center, for her critical review of the manuscript. The authors declare there are no conflicts of interest.

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