frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 21 November 2024
DOI 10.3389/feduc.2024.1485491

OPEN ACCESS

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RECEIVED 23 August 2024
ACCEPTED 04 November 2024
PUBLISHED 21 November 2024

CITATION
Noyes K, Treibergs K, Burbach SM, Stetzer MR, Smith MK and Couch BA (2024) How and why instructors use open access lessons.
Front. Educ. 9:1485491.
doi: 10.3389/feduc.2024.1485491

How and why instructors use open access lessons

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Introduction: Open educational resources (OERs) provide instructors access to no-cost lesson materials they can incorporate into their courses. OER lessons can promote the use of innovative and evidence-based educational practices in biology education. Prior research suggests that teaching strategies are often implemented in different ways which can impact student learning. However, few studies have explored how OER lessons are modified to fit their local context.

Methods: We used the teacher-curriculum framework to understand how and why instructors modify these materials. Additionally, we explored how these materials supported instructors in enacting national priorities from Vision and Change. We surveyed 139 instructors who implemented lessons published in *CourseSource*, a peer-reviewed journal specifically designed to share OERs.

Results: We found that the majority of instructors who used the lesson materials (e.g., slides, worksheets, assessments, protocols) did so without making substantial modifications, in contrast with prior research. Furthermore, we found that these materials were particularly helpful in incorporating student-centered teaching practices, like group work or discussions, sometimes for the first time.

Discussion: These insights into what instructors value in lesson materials can inform OER publishing guidelines so that these materials best meet instructional needs.

KEYWORDS

core concepts, core competencies, fidelity of implementation, open education resources, Vision and Change

Introduction

Open education resources (OER) facilitate the diffusion of knowledge by providing freely accessible teaching materials (Diaz Eaton et al., 2022; Smith, 2018). Published lessons are one type of OER that is particularly useful to instructors interested in transforming their teaching. Here, we define an OER lesson as a shareable guide and associated materials that facilitate implementation of a structured teaching activity. To be successfully implemented by another instructor in a novel class context, lessons must provide sufficient detail about the teaching activity, relevant context about past implementation, and all supporting materials (e.g., slides, worksheets, assessments, protocols). OER lessons offer an effective means for sharing effective practices within the biology education community by guiding users to adopt new, vetted, research-based pedagogical techniques without having to develop lessons from scratch. As stand-alone and shareable units with potential for large-scale dissemination through peer-reviewed journals or online resource repositories, OER lessons have the potential to support nationwide efforts toward instructional change (American Association for the Advancement of Science, 2011; Smith, 2018).

Recognizing this potential to promote widespread change, the *Vision and Change* report published in 2011 called specifically for dissemination of student-centered teaching resources, such as OER lessons, as a means to achieving its curricular and pedagogical goals (American Association for the Advancement of Science, 2011). Vision and Change (V&C) was a decade-long endeavor that drew upon community discussions, expert viewpoints, and education research to improve how undergraduate biology is taught in the United States. The 2011 V&C report offers a roadmap for uniting biology education under a set of core concepts and competencies and fostering student-centered teaching approaches. V&C led to the creation of the open access, peer-reviewed online journal *CourseSource* (Wright et al., 2013). *CourseSource* focuses on capturing detailed examples of effective teaching by publishing articles that contain student-centered, research-based OER lessons that align with V&C principles and professional society learning goals. The articles are freely accessible to all users, and the associated lesson materials are available to download for registered users (registration is free of charge). Since its founding, *CourseSource* has grown to include over 300 peer-reviewed lessons in a variety of biology subdisciplines, with an audience of over 10,000 registered users.

Despite OER lessons having the potential to support improvements in undergraduate biology education, few studies have explored the nuances of how and why instructors use these teaching materials, particularly with respect to the specific ways that instructors adapt these materials for their own contexts. Previous research has identified the broader ways instructors engage in the curriculum implementation process, including making choices about what tasks are selected for students, how tasks are enacted in the classroom, and how lessons fit into a broader curriculum (Remillard, 1999). Researchers have also defined a series of phases depicting *how* instructors use lessons. These phases include choices made about the lesson structure, content, and delivery as well as student perceptions in response to the instruction (Furtak et al., 2008). These choices surrounding instruction can impact the fidelity of implementation, defined as "the extent to which an enacted program is consistent with the intended program model" (Century et al., 2010). In light of this research, the National Research Council's report on discipline-based education research (DBER) called for further investigation to better understand changes in how instructors implement certain teaching practices and how these changes impact student outcomes (National Research Council, 2012).

Research in STEM education has explored how instructors implementing an existing teaching strategy make changes based on personal preference and teaching context, sometimes deviating from what the developer intended (Dancy and Henderson, 2010; Henderson and Dancy, 2009; Turpen and Finkelstein, 2009). For example, when using a polling question (e.g., clicker) in the classroom, an instructor may not provide sufficient time to think deeply about the question or an opportunity for students to discuss with their classmates, and these decisions may create different classroom environments and may impact the efficacy of the pedagogical technique (Turpen and Finkelstein, 2009; Lewin et al., 2016). Variation in the fidelity of implementation of active learning approaches has also been suggested to impact student outcomes in studies from biology education (Andrews et al., 2011; Offerdahl et al., 2018; Stains and Vickrey, 2017; Weir et al., 2019).

Much of this prior work studying fidelity of implementation has focused on broader teaching strategies (e.g., polling questions, active learning) rather than more detailed materials found in OER lessons, which include teaching strategies along with specific curricular topics, concepts, and competencies. One of the few studies investigating OER lesson implementation found wide variation among biology instructors implementing the same lesson in terms of both time spent using active learning (25–90% of class time) and student success on related exam questions (Pelletreau et al., 2018). Additionally, a survey of *CourseSource* users found that instructors who used OER lesson materials generally changed the materials prior to implementation (Senn et al., 2022). Given the possibility of OER lessons being a promising outlet for the dissemination of evidence-based teaching methods (Smith, 2018), it is important to understand how such OER lessons are enacted in the classroom.

Our research investigates the choices and experiences of instructors as they enact OER lessons that have previously been developed and published by peers in the undergraduate biology education community. This study was guided by Remillard's (2005) teacher-curriculum relationship framework, which characterizes the way instructors interact with curricular materials to influence the enacted curriculum. The teacher-curriculum relationship framework was developed to support curriculum and pedagogy reform efforts in mathematics education, amidst efforts for adopting a new standards-based national curriculum (Remillard, 1999, 2005). The original context for this framework echoes the curricular and pedagogical transformation recommended by the V&C initiative.

This framework depicts the interactive relationship between instructor and curriculum during the planning and enactment of the curriculum, suggesting that it is not sufficient to solely consider instructor or curriculum alone. The knowledge, experiences, perceptions, and identities of an instructor can influence the way they interpret and enact a lesson in their course, just as the lesson itself (including the knowledge, experiences, perceptions, and identities of the lesson developer) can influence the behavior of the instructor (Remillard, 1999, 2005).

The teacher-curriculum framework defines the curriculum as "printed, often published resources designed for use by teachers and students during instruction" that may include representations of concepts, material objects, representations of tasks, and other details about lesson implementation (Remillard, 2005). In our study, the "curriculum" is represented by peer-reviewed lessons published in *CourseSource* by instructors that have previously taught the material to undergraduate students. To be published, the author guidelines specify that each article must contain a comprehensive set of materials that "allow easy implementation by a broad range of faculty." Each article is structured according to a detailed template that prompts authors to include specific sections: scientific teaching context (e.g., learning goals and objectives), introduction (e.g., intended audience, prerequisite knowledge), scientific teaching themes (e.g., active learning, assessment, inclusive teaching), lesson plan, teaching discussion, and supporting materials (Article Template, 2023). This structure is intended to help ensure the consistency and user-friendliness of the materials.

The "teachers" in this study are instructors who use *CourseSource* lessons. A prior survey of *CourseSource* users revealed that these individuals are primarily professors and lecturers who come from a range of degree-granting institutions and spend over half of their time teaching (Senn et al., 2022). Additionally, a majority of *CourseSource* users adapt existing lesson materials for implementation in their courses, with 86% of users making modifications to the lesson and timeline and 73% of users making modifications to the supporting lesson materials (e.g., worksheets, lecture slides) (Senn et al., 2022). This finding that instructors make modifications to these OER lessons aligns with other prior research regarding the implementation of broader teaching strategies (Dancy and Henderson, 2010; Henderson and Dancy, 2009; Turpen and Finkelstein, 2009). Despite this research, it is not yet understood what specific modifications instructors make to OER lessons, why they make those changes, and how these changes eventually impact students (Figure 1).

The current study focuses on the relationship between the instructor and OER lesson. To explore instructors' use and modification of OER lessons in greater detail, we surveyed a large audience of *CourseSource* users about how they leverage lesson materials in their teaching. *CourseSource* was created in response to a need for community-wide sharing of curricular materials expressed in the 2011 V&C report, so its instructional materials are structured to explicitly align with V&C principles (Dolan, 2012). Considering this, we also sought to understand to what extent using these lessons helped instructors incorporate V&C principles into their teaching. Lastly, to support future adoption of these resources, we asked instructors to share how their use of these lessons has impacted their teaching, including what they found to be most useful as well as what improvements could be made. We summarize these objectives as the research questions guiding our study:

1. How do instructors use OER lessons in their teaching?
2. To what extent do OER lessons help instructors incorporate V&C principles into their teaching?
3. In what ways do instructors perceive that their use of OER lessons has impacted their teaching?

Materials and methods

Data collection

To address our research questions, we developed a survey to probe the use of OER lessons and associated materials. While we were broadly interested in general OER use, we focused solely on instructors who had used materials published in *CourseSource*. By focusing on one OER journal, we could reduce the variability in lesson structures and detail that exists across the range of OER journals, websites, and other repositories. *CourseSource* users also have the free opportunity to become registered members of the site, which provided us with the means of contacting a targeted population of potential survey participants. As part of the *CourseSource* terms of service, users agree that they may be contacted to voluntarily participate in research. This research was classified by the University of Nebraska-Lincoln as exempt from Institutional Review Board (IRB) review under protocol 22214.

We solicited participation from users who downloaded at least one of 40 identified *CourseSource* articles. These 40 articles consisted of the top 20 most downloaded articles of all time and the top 20 most downloaded articles published recently (September 2021 to January 2023). In the end, we contacted 4,978 registered *CourseSource* users, sending them a link to our survey published through the Qualtrics online survey platform (Qualtrics, 2024). Those who downloaded the article may not have used the lesson materials in their course, but by sending it to a broader pool of individuals, we could hopefully capture the instructors who had used these materials. 435 potential participants opened the link, and 139 participants met our qualifying criteria and completed the survey. The qualifying criteria required that the participants used some portion of the lesson materials (either directly or for inspiration) for at least one of the identified articles at a 2- or 4-year higher education institution in the United States. Additionally, to satisfy IRB requirements, the participants acknowledged that they were located outside of the European Union, were at least 19 years of age, and agreed to our informed consent form.

We began our survey development process by reviewing the questions used in a previously published survey of *CourseSource* users (Senn et al., 2022). While this previous survey focused on more general use of *CourseSource* materials (e.g., "how do you typically use *CourseSource* lessons"), our survey focused on the use of one specific lesson (e.g., "how did you use the materials associated with this particular *CourseSource* lesson"). The survey was refined based on several rounds of feedback from both inside and outside of the research team. Once we felt that the questions captured the targeted dimensions, we piloted the survey with members of the *CourseSource* editorial team and other individuals within our professional network who had familiarity with *CourseSource* ($N = 16$). One of the pilot participants completed the survey as a think-aloud interview, which enabled us to further monitor interactions with the survey format. The pilot participants came from a range of associate's, baccalaureate, master's, and doctoral granting institutions; this helped ensure that our survey could capture the experiences of OER users at a variety of different institution types. The final survey questions are included in Supplementary Materials 1.

The finalized version of the survey asked participants about many different aspects of their experience using a *CourseSource* lesson, but in this study, we focus on three sections corresponding to our research questions. To explore how the participants used the lesson (RQ1), we asked participants questions about how they used the supporting lesson materials, specifically the lecture slides, worksheets, assessment questions, and lab protocols. For those who used these materials directly in their course (as opposed to as inspiration), we then asked about any modifications they made to incorporate them into their course. To examine how the use of the OER lesson helped participants incorporate V&C principles (RQ2), we asked questions about which ideas (corresponding to the V&C core concepts, core competencies, and other evidence-based practices) were present in the *CourseSource* lesson and to what degree each was helpful to their instruction. Finally, we asked

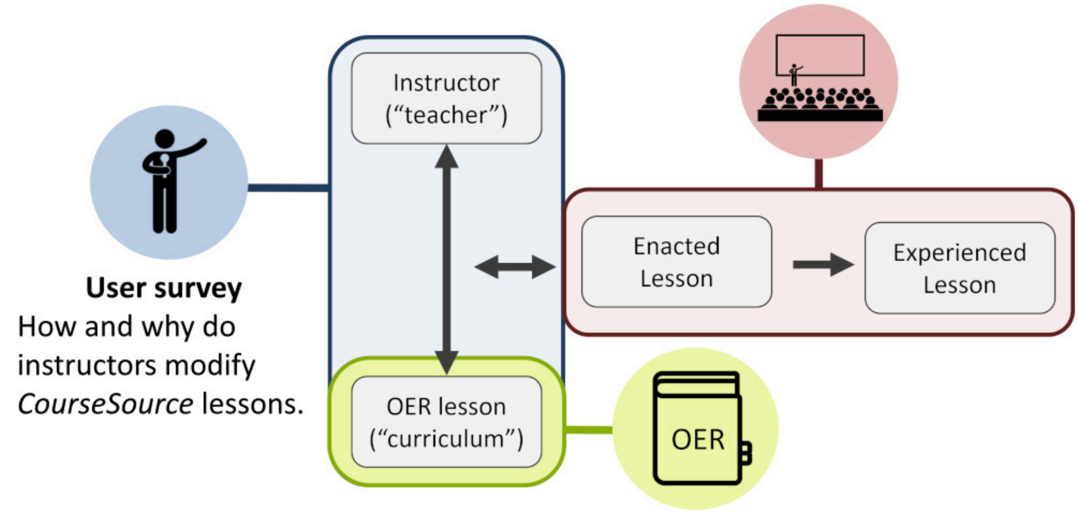

FIGURE 1
Overview of process by which an OER lesson reaches students mapped on to the teacher-curriculum relationship framework (Remillard, 2005).

the participants to indicate what aspects of their teaching were impacted by the use of the lesson and to elaborate on the ways in which they were impacted (RQ3).

Participants

In addition to questions about the topics above, we collected demographic information about the participants (N = 139). We asked participants about their gender and racial/ethnic identities, their academic position and institution, their familiarity with V&C, and the course in which they used the OER lesson. We include a summary of the demographic information in this section and in Figure 2; full information can be found in Supplementary Materials 2. Based on this information, we found that teaching was a priority for the participants and their institutions. More than half of our participants taught at an associate's, baccalaureate, or master's institution, and they primarily held positions where teaching made up the majority of their responsibilities. These instructors also had experience teaching their associated courses with about 70% of the participants reporting that they had taught the course in which they used the OER lesson for at least 3 years.

Data analysis

We analyzed the responses to both closed-ended and open-ended survey questions. In the following paragraphs, we describe the coding process and codebooks for the two open-ended questions hereon referred to as "motivation for modification" and "teaching impact." To summarize trends within open-ended and closed-ended responses, we calculated descriptive statistics using the statistical software SPSS (IBM Corp, 2021). For quantitative comparisons, we used Pearson's χ^2 tests to analyze associations between variables (Agresti, 2007). We used a significance level of 0.05 and, where appropriate, we used a Bonferroni corrected significance level to account for increased risk of a type 1 error (i.e., false positives) (Bland and Altman, 1995). Additionally, we used Cohen's suggestions for interpreting the effect size (φ) (Cohen, 1992).

Motivation for modification

For each lesson material type (lecture slides, worksheets, assessment questions, lab protocols) participants were asked to indicate if they used that material directly in their course with significant changes or minimal/no changes (Q4.2 in Supplementary Materials 1). Those who indicated making significant changes were then asked a pair of follow up questions (1) about why they changed the materials and (2) to provide a specific example of how they changed the materials (Q4.5–Q4.6 in Supporting Materials 1). If participants reported modifying multiple material types, we asked them these two questions for each material they changed.

Authors KN and SB analyzed the participants' reasons for modifying the materials. We read through and familiarized ourselves with the responses (N = 49) and identified three emergent, non-mutually exclusive codes to characterize overall motivations for modifying the materials (Table 1). We analyzed their response to why they changed the materials and their example of how they changed their materials together in case the participant addressed their motivation for modifying the materials when discussing the example of their modifications. We then independently coded all responses in the current data set, met to discuss any disagreements, and came to consensus on any disagreed upon codes. Cohen's kappa values for initial agreement for each of the three codes ranged from 0.702 to 0.935, corresponding to "substantial" to "almost perfect" agreement (Cohen, 1960; Landis and Koch, 1977). The final consensus codes were used in our analysis.

Teaching impact

Participants were also asked to reflect on the impact of using the lesson on their teaching (Q6.1 in Supplementary Materials 1). Those who indicated that their teaching was impacted by their use of the *CourseSource* lessons were asked to elaborate

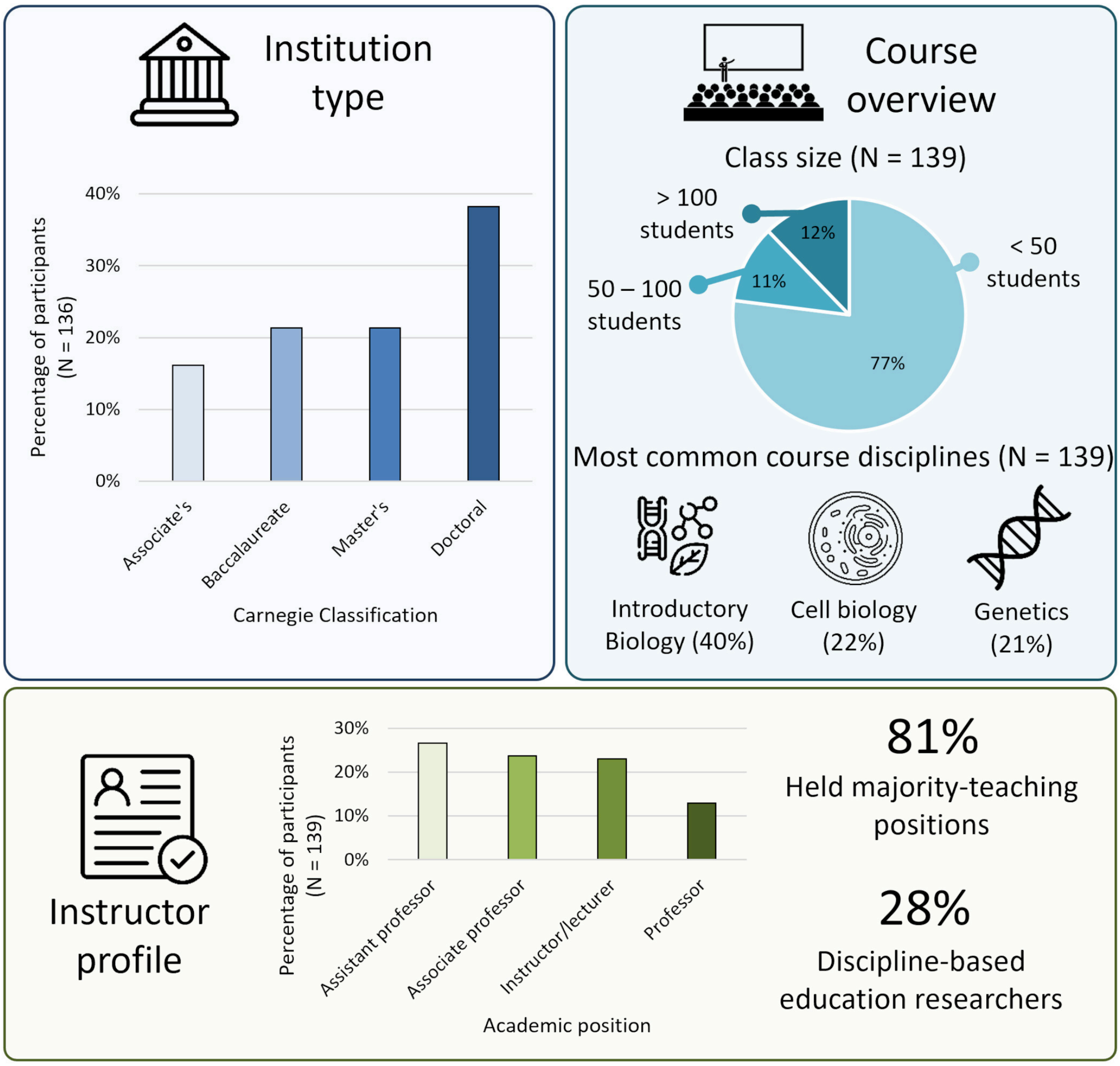

FIGURE 2
Summary of key participant information. Complete information is provided in Supplementary Materials 2. Institution type was determined using the Carnegie Classification system (Indiana University Center for Postsecondary Research, n.d.). Majority-teaching positions were defined as those with 51% or more of their positions designated for teaching.

in an open-ended response. Authors KN and KT conducted the analysis of those responses ($N = 133$). We familiarized ourselves with the responses and discussed the patterns present. From this familiarization process, we generated a list of analytic, non-mutually exclusive codes characterizing the self-reported positive teaching impacts associated with using the lessons (Table 2). We focused on the positive aspects because, as we discuss in the results, very few participants ($N = 3$) identified that using the lesson had a negative impact on their teaching.

To optimize interrater reliability (IRR), we independently coded sets of 40 responses. After each round, we calculated Cohen's kappa to assess our initial agreement to ensure that all codes had a value greater than 0.7 (indicating "substantial" agreement) (Landis and Koch, 1977). If any codes had a value of less than 0.7, we discussed why we disagreed and made any appropriate changes to the coding scheme. After three rounds, we reached IRR for all teaching impact codes with Cohen's kappa values ranging between 0.776 and 1.000. We then used the finalized codebook to independently re-code all the responses and came to consensus on any disagreements. The final consensus codes were used in our analysis.

Article subset

In the first section of the survey, participants selected one of the 40 articles to focus on for the remainder of the survey. Thirty-four articles were selected at least once, and the three most popular articles generated more than 10 responses each. While we report the aggregate results of all the articles, we also highlight responses from these three frequently used articles to give additional context for our results and discuss potential differences in how the lessons are used. The three articles in this subset are "Why Meiosis Matters: The Case of the Fatherless Snake," "Using the Cell Engineer/Detective Approach to Explore Cell Structure and Function," and "Dilution and Pipetting Lesson Using Food

TABLE 1 Codes characterizing motivation for modification.

Code name	Description	Example quote
Logistics	The participant changed the materials due to the format of the course or another logistical aspect. For example, changes made due to the length of the class, modality of an assessment, or availability of a resource.	• "*[O]riginal paper had multiple modules that should each take 1–2 h to complete; I shortened to fit into 2 50-min class times, therefore the assessment questions had to change...*" • "*I also change formatting substantially so that the worksheets 'look the same' as the ones I typically write for students.*"
Content	The participant changed the materials to cover specific course content or meet a learning objective. For example, changes made to incorporate additional background information or to focus on different phenomena.	• "*I wanted to add some additional questions so the students would be familiar with these aspects later in the course.*" • "*I provided more background information on certain topics-i.e. DNA barcodes or sequencing. Mostly just added more details.*"
Audience	The participant changed the materials to meet the needs or local context of the intended audience of the lesson. For example, changes made due to the experience/background of the students or to incorporate locally-relevant details.	• "*My students are from diverse academic backgrounds and abilities. I modified the lecture slides to make them more accessible to a broad audience.*" • "*[I] reduced complexity for first-year students to more easily complete with limited biology backgrounds.*"

Dyes" (Burnette et al., 2016; Sestero et al., 2014; Wright, 2014). For simplicity, we refer to each article and their associated lessons and materials as "Snake," "Cell," and "Pipette" throughout this manuscript. The Snake lesson uses an interesting phenomenon to teach meiosis and mitosis. The Cell lesson uses a group exercise to teach students about eukaryotic cell structure and the relationship between structure and function. Finally, the Pipette lesson uses food dye to teach pipetting and dilution techniques. Brief summaries of each of the three lessons (adapted from their respective article abstracts) are shown in Figure 3.

Results

RQ1: How do instructors use OER lessons in their teaching?

The majority of participants reported only a minimal (57%, $N = 79$) or a moderate (41%, $N = 57$) difference in the alignment of the learning goals of the *CourseSource* article and the learning goals they had for their own lesson implementation. This could explain why 60% of the participants reported using the supporting lesson materials directly in their course (hereon referred to as "direct users") as opposed to using the materials in another way, like as a source of inspiration. We followed up with the direct users to explore their use of lecture slides, assessment questions, worksheets, and lab protocols (Figure 4).

When enacting the materials, the majority of direct users (64–89%, depending on the lesson material type) typically did so with either no changes or minimal changes (Figure 4). Using Pearson's χ^2 tests, we found significant associations between the participants' use of the materials and their perceived alignment of the learning goals. Due to the low numbers of participants reporting completely different learning goals compared to the *CourseSource* article ($N = 3$), we combined those participants with those reporting moderately different learning goals ($N = 57$) for this statistical test. We identified a positive association of medium effect size between direct use of the materials and having identical or minimally

TABLE 2 Codes characterizing teaching impact.

Code name	Description	Example
Science competencies	The students' understanding of technical skills, practices, or other aspects of the scientific process were impacted.	"*[I]t encouraged critical thinking, good classroom discussions, and keen observation skills.*"
Disciplinary concepts	The students' understanding of disciplinary concepts were impacted.	"*It gives students the opportunity to interact with each other and not just memorize organelles, but focus on how the structure of the cell relates to different cellular functions.*"
Authentic application	The students had the opportunity to engage with authentic or "real world" phenomena, data, or issues.	"*This research opportunity allowed my students to explore technology that is cutting edge... Overall I feel providing them with this CURE allows them to experience authentic research that they might not receive in their degree otherwise.*"
Student satisfaction	The students valued, appreciated, or enjoyed the lesson.	"*It is a fun way to practice pipetting.*"
Instructor positive affect	The instructor had a positive affective experience using the lesson. This includes feelings of being satisfied, encouraged, inspired, reassured, and other positive emotions.	"*I felt reassured to have one model of a full semester-long CURE to use as a guide as I was designing and preparing my own materials for my course.*"
Instructor pedagogical growth	Using the lesson helped the instructor to try a new teaching or pedagogical technique.	"*This article not only contained a lesson relevant to my lab course, but also provided me a template for how I might effectively organize student handouts for other lab activities.*"
Ease of use	The instructor saved time or experienced another positive practical impact by using the lesson.	"*I've struggled with finding enough time to develop my own engaging active learning activities, and it was lovely to have something that matched my goals that was more plug-and-play so that i could focus on other aspects of my course.*"

Snake
N = 11

Why Meiosis Matters: The Case of the Fatherless Snake
This lesson features the compelling story of a "fatherless snake." The puzzle motivates students to learn about meiosis and mitosis, since the only way to explain the origin of the fatherless baby is by mastering details of meiosis. During the process, students work through the major steps in meiosis, compare and contrast mitosis and meiosis, and apply their understanding to predict how meiosis "went wrong" to produce an unusual offspring that did not originate through union of an egg and a sperm.

Cell
N = 12

Using the Cell Engineer/Detective Approach to Explore Cell Structure and Function
The overall objective of this teachable unit is to help students learn basic components of eukaryotic cells and understand the connection between cellular structure and function using active learning approaches. The key component of this teachable unit is a group exercise. In this exercise, students work in groups to design a cell that is well suited for a function that is provided to them by the instructor (Cell Engineer). The groups then exchange their cells with classmates and try to guess the function of their classmates' cells (Cell Detective).

Pipette
N = 10

Dilution and Pipetting Lesson Using Food Dyes
In this lesson, students learn how to use micropipettors to accurately measure small volumes of liquids and perform dilutions using food dyes. Students dilute four food dyes at 10X concentration to 1X working stocks. Using the formula c1v1=c2v2 each student completes a table requiring four dilution calculations for different final volumes. Using the values they generated, students make the solutions of 1X food dye. Reference solutions furnished by the instructors provide students with immediate feedback and self-assessment.

FIGURE 3
Summaries of the three lessons in the article subset (Burnette et al., 2016; Sestero et al., 2014; Wright, 2014).

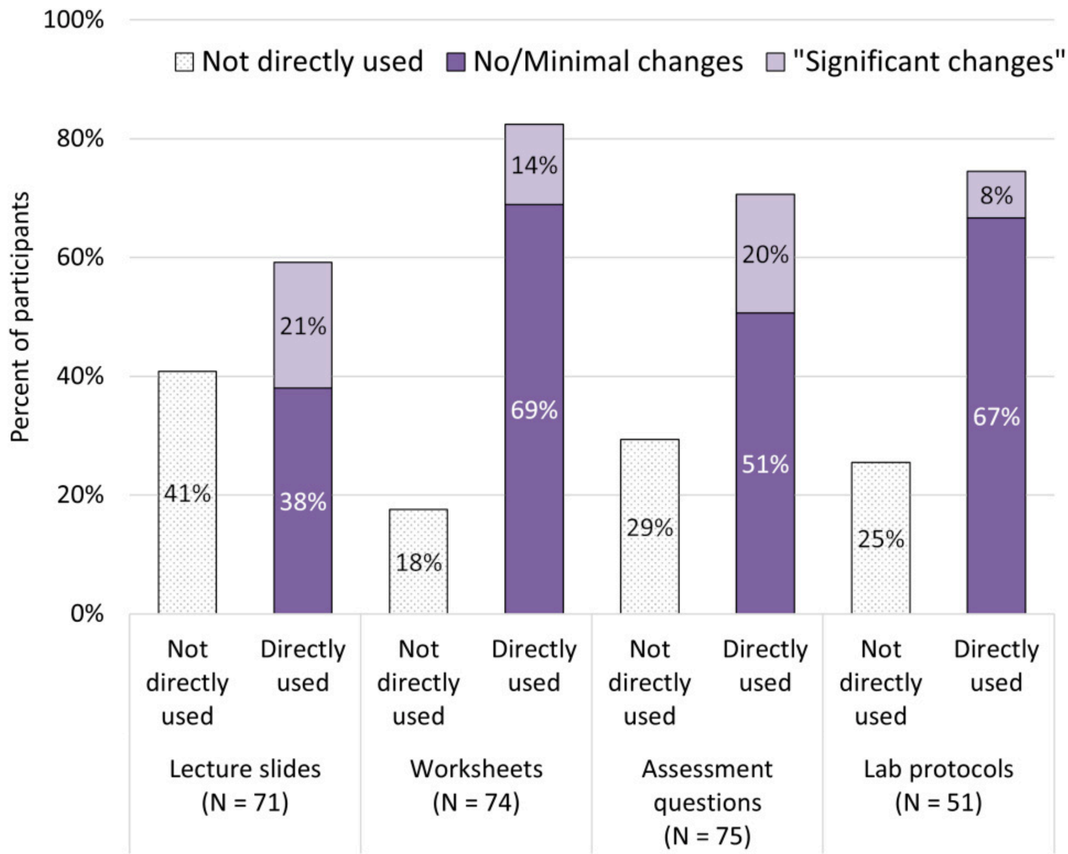

FIGURE 4
The proportion of participants who directly used the lesson materials in their course (if they were included in the original published article) and the percentage of those direct users who used the materials as written or made modifications to the materials.

different learning goals (χ^2 = 12.907, P < 0.001, φ = 0.305). Similarly, we identified a positive association of medium effect size between using the materials for inspiration and having moderately or completely different learning goals (χ^2 = 11.773, P < 0.001, φ = 0.291).

Of the 72 direct users who did not make significant modifications, the vast majority (94%, N = 68) indicated that "*the materials matched what [they] wanted.*" Additionally, few reported that they did not have enough time/resources to change the materials (15%, N = 11) or that the materials were difficult to change (1%, N = 1). We also asked the 34 participants who made at least one significant change to the materials to explain why they made those changes (see "motivation for modification" subsection of the methods). We found that participants modified materials primarily due to the content of the material (76%, N = 26), but logistics (47%, N = 16) and audience (26%, N = 9) also played a role (code descriptions in Table 1). To contextualize these findings, we highlight below some individual examples explaining the reasons why participants changed the lesson materials associated with the article subset.

Participants discussed making modifications to the content of the material to address certain topics or learning objectives not included in the lesson. Often, this involved adding new phenomena to the lesson. For example, one participant who used the Cell lesson added "*a couple more cell type versions: plant hair cells (absorb water and nutrients from the soil), animal neuron (conduct electrical currents over large distances), animal motile cell (actively change length and shape to produce force or motion).*" Another participant changed the Snake lesson to highlight a similar phenomenon occurring in a different species: "*I added an example of bird sex determination because we had been talking about turkeys in the class (and they have been shown to undergo parthenogenesis as well).*" Other participants added specific content or ideas that they felt was important to address in their course but may not have been included in the *CourseSource* lesson materials to the degree they desired.

Logistical changes were often made to account for the length of the class or the number of students in the class. Other logistical reasons pertained to the resources instructors had access to. For example, one participant who used the Pipette lesson tweaked the calculations for different sections of the course to reuse materials: "*Using food dye is a very practical way and cheap to make variations for serial dilutions. For example I use a color for each day of the week when assessing serial dilutions, in addition I change the dilutions factor. For example for Monday morning I use red 3X for Monday afternoon red 4X.*"

Finally, some changes were made to the lesson materials to better serve the specific audience of the course. Often, the participants referred generally to making the materials simpler or more advanced depending on the level of the students. These responses rarely went into depth about what those changes entailed. For example, one participant using the Pipette lesson reported "*I used this for a biochemistry class, so I changed the intro text to reflect that.*" They elaborated on this point mentioning that "*on a more cosmetic level, I changed all liter symbols to 'L,' as the students see it written that way,*" but it is unclear if the change in unit abbreviation was the only change made to better suit the needs of the biochemistry students.

RQ2: To what extent do OER lessons help instructors incorporate V&C principles into their teaching?

In the survey, we asked participants to reflect on how different ideas, corresponding to V&C principles, were addressed in the lessons. Specifically, we focused on four broad principles outlined in V&C: core concepts, core competencies, student-centered learning, and diversity, equity, inclusion, and belonging (DEIB) (American Association for the Advancement of Science, 2011; American Association for the Advancement of Science, 2018). Although 76% (N = 105) of participants reported that they were familiar with V&C, we wanted participants to reflect on the principles (rather than the V&C report), so we did not mention V&C by name in this section. From their responses, we determined (1) whether the participant identified that the idea was present in the *CourseSource* lessons and (2) the degree to which the lessons were helpful in addressing that idea (Figure 5). In the following paragraphs, the names of the V&C ideas are bolded.

Core concepts and competencies

The core concepts and competencies represent the important ideas that run throughout all of biology, and, perhaps unsurprisingly, nearly all the participants identified at least one core concept (88%, N = 123) or competency (96%, N = 133) as present in the lessons. However, there was a wide range in the frequency at which the core concepts (31–71%) and competencies (47–81%) were identified as present (Figure 5). Furthermore, the majority of those who identified that a particular core concept or competency as included felt that the lessons were either "somewhat" or "very helpful" at addressing the idea.

When submitting to *CourseSource*, the author(s) must identify the core concepts and competencies addressed in the lessons. This provided us with the opportunity to assess the alignment between core concepts and competencies identified by lesson author(s) and our study participants. Using a series of Pearson's χ^2-tests, we found significant associations for 6 of the 11 core concepts and competencies suggesting good agreement between the authors and participants for those particular ideas (Table 3).

Examining the alignment of core concepts and competencies of the article subset helped contextualize these results. Additionally, this provided a look at the perceptions of multiple users of a single article's lessons. In Figure 6, we show the author-identified core concepts and competencies and the breakdown of the number of participants who saw the ideas as present and the lesson as helpful (either "somewhat helpful" or "very helpful") in expressing the idea. In general, there was good agreement between authors and participants with the exception of the Cell lesson. Nine of the 12 participants who used the Cell lesson did not feel that the author-identified core competency of modeling was present. Instead, most participants (N = 8) identified the process of science as present.

Student-centered learning techniques

Of the four student-centered learning techniques (Figure 5), nearly all participants (> 87%) reported that the lesson provided opportunities for student discussion, group work, and assessments to gauge student understanding. Additionally, participants most often felt that these materials were "very helpful" (47–58%) in

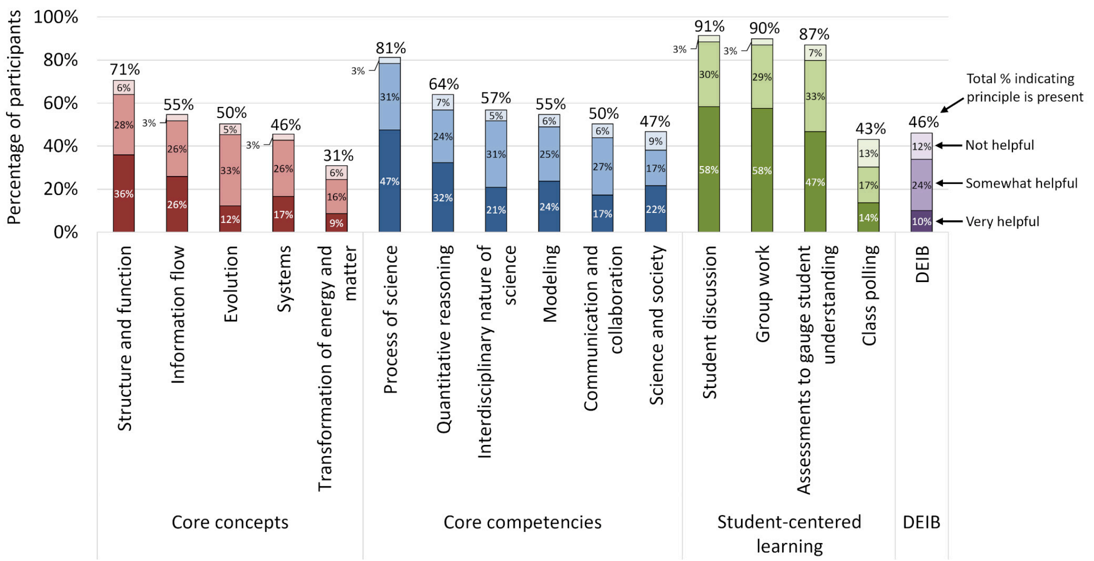

FIGURE 5
The percentage of participants who identified each idea as present, not helpful, somewhat helpful, and very helpful. The broader V&C principle associated with each idea is shown at the bottom of the graph. Within each V&C principle, the individual ideas are arranged in decreasing order of prevalence. All 139 respondents responded to each question except for systems (N = 138) and class polling (N = 138).

TABLE 3 The results of the Pearson's χ^2-tests comparing the alignment between the author- and participant-identified core concepts and competencies.

Core concept or competency[a]	χ^2 value	P-value[b]	φ[c]
Evolution (concept)	**16.007**	**< 0.001***	**0.339**
Information flow (concept)	**41.013**	**< 0.001***	**0.543**
Structure and function (concept)	**9.153**	**0.002***	**0.257**
Systems (concept)	3.892	0.049	N/A
Communication and collaboration (Competency)	7.573	0.006	N/A
Interdisciplinary nature of science (competency)	**11.143**	**< 0.001***	**0.283**
Modeling (competency)	0.448	0.503	N/A
Process of science (competency)	6.735	0.009	N/A
Quantitative reasoning (competency)	**28.321**	**< 0.001***	**0.451**
Science and society (competency)	**19.143**	**< 0.001***	**0.371**

[a]Statistical test not run for **transformation of energy and matter** due to small expected counts. [b]For the 10 tests, Bonferroni corrected p-value is 0.05/10 = 0.005. Significant results are marked with "*." [c]Effect size values: small—0.1, medium—0.3, large—0.5 (cite Cohen, 1992). Significant results, indicating author and participant alignment, are bolded. The rows are separated by core concepts and core competencies and then ordered alphabetically.

supporting these opportunities. This is in contrast with the class polling opportunities which the majority of participants did not see as present in the lesson they used.

Student-centered learning techniques were present in all three of the lessons in the article subset, and based on the content of each lesson, we can identify portions that likely influenced the participants' responses. Beyond providing an interesting phenomenon, the Snake lesson includes thought-provoking questions to ask the class which could be why all 11 participants reported that the lesson was "very helpful" in supporting student discussion. The Cell lesson centers around an activity that students do as groups and also contains discussion opportunities both within the groups and for the full class. Not only did the participants overwhelmingly report (11 of 12 participants) that the lesson was "very helpful" in providing opportunities for student discussion, but group work as well. Finally, the Pipette lesson does not provide explicit student discussion prompts or group work activities, but it does feature a novel way to approach assessment by providing a visual way to see if the students had correctly calculated and carried out the appropriate dilution. This could be why 8 of the 10 participants who used this lesson reported assessments to gauge student understanding were present (5 of which reported the lessons were "very helpful" in this regard).

Diversity, equity, inclusion, and belonging (DEIB)

About half of the participants (46%, N = 64) saw DEIB as present in the lesson (Figure 5). However, only 10% of the participants found that the lessons were "very helpful" in supporting DEIB. We found similar patterns in the results of the article subset. Across the three lessons, the majority reported that DEIB was not included, and only 4 participants (Snake: N = 1; Cell: N = 1; Pipette: N = 2) reported that the lessons were "very helpful" in supporting DEIB. From their written responses explaining how they used the lessons to support DEIB, two participants (Snake and Cell lesson) discussed how they used the lessons to incorporate group work which enabled them to help diverse groups of students work together. For the Pipette lesson, one participant discussed how the approach to assessment was more approachable and welcoming to their students as they were given credit for completion and not necessarily accuracy. The other participant who used the Pipette lesson mentioned that (while they had not done so already), the use of rainbow of colors could be used to incorporate a discussion to highlight LGTBQ+ scientists.

RQ3: In what ways do instructors perceive that their use of OER lessons has impacted their teaching?

When asked about how these lessons impacted their teaching, the participants reported an overall positive impact in all four dimensions investigated (Figure 7). While student learning and engagement was positively impacted by the lesson (> 93%), student satisfaction lagged behind with only 65% indicating a positive impact. Still, it was rare for a participant to report even one negative teaching impact ($N = 3$) associated with using the lessons.

We also qualitatively analyzed their explanations of how their use of these lessons resulted in these positive impacts (see "teaching impact" subsection of the methods). We found that there were many ways in which the lessons contributed positively to the participants' teaching (Table 2 and Figure 8), but they broadly addressed (1) the content of the lesson (science competencies, disciplinary concepts, and authentic application), (2) the students (student satisfaction), and (3) the instructor (ease of use, instructor positive affect, and instructor pedagogical growth). To give context to the teaching impact analysis, we highlight quotes from the participants who used lessons from the article subset (full results of teaching impact coding of article subset in Supplementary Materials 3).

Many of the positive aspects participants experienced were related to the content of the lesson. Two of the most common codes (28%, $N = 37$, for each) pertained to science competencies (important ideas related to the practice of science) and disciplinary concepts. For example, participants who used the Pipette lesson appreciated the opportunities students had to develop their technical skills, like the act of pipetting (science competencies). For example, one participant discussed how "*It's a low-stakes, colorful, activity and the students get to see for themselves if they were able to use the equipment & do the calculations properly. They aren't relying on the instructor as the authority that judges their ability. The skills transfer to other lab protocols and the cost is low.*" This is in contrast with the Snake and Cell lessons in which participants saw benefits related to addressing discipline specific concepts like meiosis/mitosis and cell organelles, respectively (disciplinary concepts). Some participants (18%, $N = 24$) discussed how the lesson provided opportunities to engage in "real world" scientific experiences that are typically absent in the classroom (authentic application).

In addition to the lesson content, participants discussed how students found the activity fun or valuable (student satisfaction, 21%, $N = 28$). For the Snake lesson, the most common positive impact discussed was student satisfaction. For example, one participant discussed how "*The students enjoy doing something more active and collaborative in class than just listening to a lecture.*" Another mentioned that "*I feel like the article positively impacted my teaching because it made learning more fun. Instead of sitting and hearing a lecture, students were able to discuss genetic concepts in a fun way.*"

In addition to codes focused on the students' experience, participants also discussed how using the lessons had a positive effect on them as instructors. Sometimes this related to logistical challenges like the time saving benefits of using these materials (ease of use, 11%, $N = 14$). Participants also discussed how the lessons provided them reassurance or energized them (instructor positive affect, 13%, $N = 17$). However, the most common instructor-centered positive impact described that the lesson material enabled the participant to try something new (e.g., active learning) or apply an aspect of the course to a new context (instructor pedagogical growth, 27%, $N = 36$). The Cell lesson most frequently elicited responses discussing instructor pedagogical growth. For example, "*...I found it extremely helpful because this was the first time I tried to incorporate group work as a solo instructor in a large lecture course. So, I used the article as a starting point. It positively impacted my teaching by helping me feel that I had a quality activity for students to work on and some students emailed me after saying that they really enjoyed the lesson.*" Another mentioned, "*It helped me see the value of activities like this in a lab setting. It also let me see that it is feasible, even in a huge class. And, it gave me confidence to develop a new lab that other instructors in our lab team could use in their sections.*" These highlight the powerful impact these lessons can have on instructors as they try to incorporate evidence-based practices, something they may never have done before.

Discussion

RQ1: How do instructors use OER lessons in their teaching?

While prior studies suggest that instructors often vary widely in how they implement OER lessons (Pelletreau et al., 2018; Senn et al., 2022) and broader teaching practices (Dancy and Henderson, 2010; Henderson and Dancy, 2009; Offerdahl et al., 2018; Stains and Vickrey, 2017; Turpen and Finkelstein, 2009), we found that most of our participants who used lesson materials directly in their course reported doing so without significant changes (Figure 4). Furthermore, nearly all of those who used the materials with either no or minimal changes did so because the materials matched what they wanted and not for other reasons (e.g., lack of time). Additionally, those who made significant changes to the lesson materials primarily focused on adjusting the content, like adding additional phenomena or questions to the activity, to improve the alignment between the lesson materials and their course. Even though these participants characterized their changes as significant, few described a complete overhaul of the lesson materials.

Another possibility is that our survey was able to capture more specific behaviors by asking targeted questions about the use of particular lesson materials (e.g., worksheets, assessment questions). In a previous survey of *CourseSource* users conducted by Senn et al. (2022), the authors found that the majority of respondents (73%) typically made modifications to the lesson materials. However, their survey focused on the *general* use of OER lessons, while our survey asked about the use of specific learning materials associated with a specific lesson (i.e., lecture slides, worksheets, assessment questions,

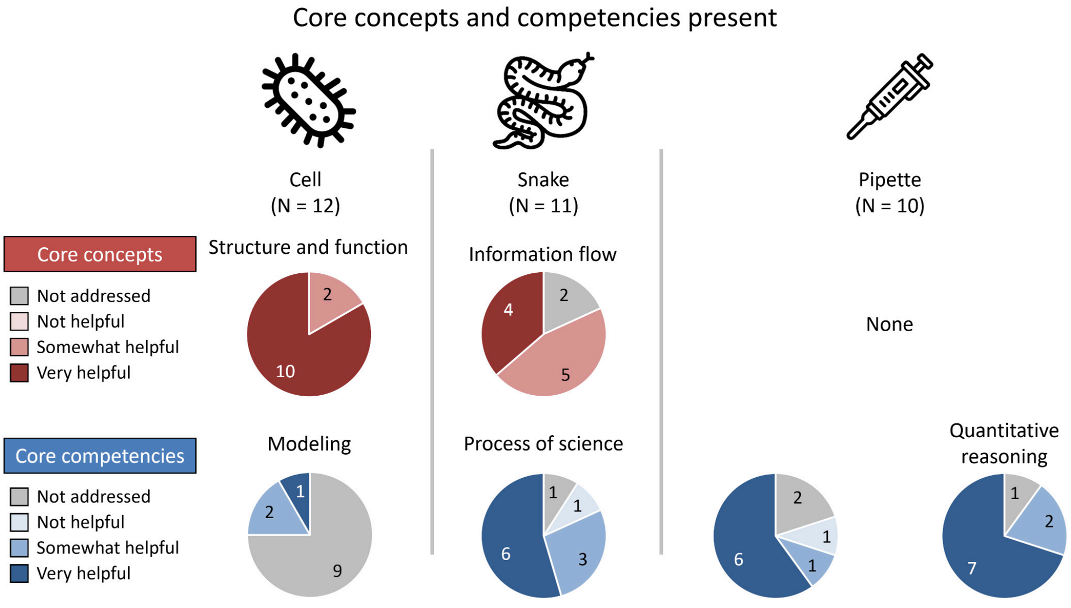

FIGURE 6
An overview of how helpful the participants found the lessons (in the article subset) to be in supporting the author-identified core concepts and competencies. Headings indicate concepts and competencies identified by authors and pie charts indicate participant viewpoints.

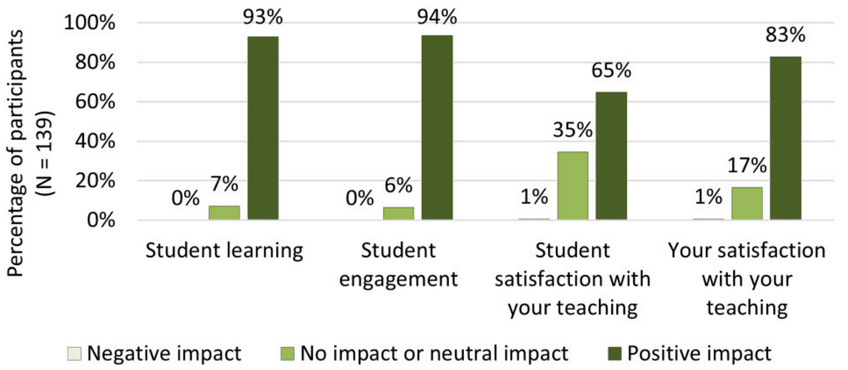

FIGURE 7
Percentage of participants reporting negative, no/neutral, or positive impact on aspects of their teaching through using the lessons.

and lab protocols). In this respect, the depth of our questioning was able to capture a different aspect of how OER materials are used, and this increased resolution allowed us to see how the changes made to lessons typically maintain the core activity components.

We were surprised to find that many of these lesson materials were used without significant modifications. Even beyond what the literature states, in our experiences, using such materials in our own classes has been accompanied with some changes to make them "fit" within the context. This reflects the possibility that instructors may *feel* that they are making more changes than they actually are. That is, the changes turn out to be smaller than initially believed when asked to reflect further. This could explain why so many of the explanations of the "significant" changes made to the materials are more appropriately described as minor modifications (e.g., including additional phenomena or modifying activity logistics).

With respect to the teacher-curriculum framework, we see evidence that our teachers (instructors) make what they view as necessary, but perhaps relatively minor, adaptations to the curriculum (OER lesson) that enable it to work for their given context. This is encouraging as this suggests that these participants are potentially valuing and enjoying the benefits associated with the original lesson materials. *CourseSource* articles undergo a peer-review process that not all OERs experience, and our results support the notion that the associated lessons are of high-enough quality that instructors do not feel the need to make substantial modifications. When instructors change the material significantly, they can publish a new, standalone article in *CourseSource*, but prior research suggests that this avenue is uncommon (Senn et al., 2022). *CourseSource* also provides the opportunity for users to upload their modifications to the original article webpage for others to use, though future research is needed to understand how this avenue is used. The sharing of lesson modifications also opens the door to potential issues regarding credit, ownership, and copyright. To help instructors navigate these challenges, our broader research

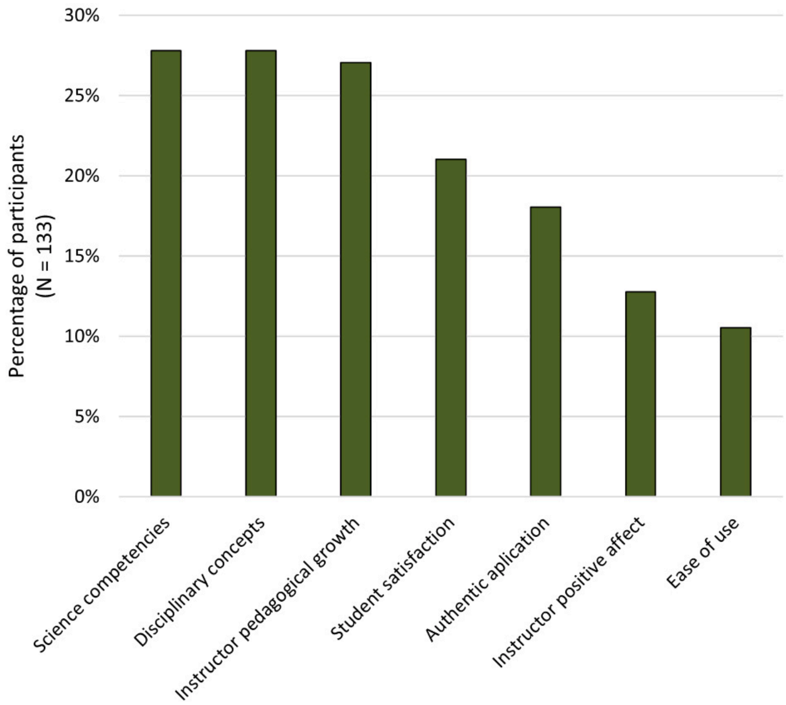

FIGURE 8
The prevalence of each of the categories used to code the teaching impact responses. The categories are arranged from left to right in order of decreasing prevalence. The most common teaching impact code for each of the lessons in the article subset is also included.

team created the ORBE (Open Resources for Biology Education), which compiles information about popular OERs including their policies regarding use and adaptation (Ahmed et al., 2024).

Still, our findings raise the question of how these changes, even minor ones, impact the effectiveness of the lesson. Prior research has delineated the core aspects needed for a particular teaching strategy to support student outcomes (Offerdahl et al., 2018; Stains and Vickrey, 2017) and has highlighted how different levels of student interactivity affect student learning (Andrews et al., 2011; Pelletreau et al., 2018; Weir et al., 2019), but these questions have not been explored extensively with OER lessons. OER lessons provide an important context for future research to understand how subtle changes to the format, disciplinary content, and instructional strategies shape resulting student experiences and outcomes. This research will benefit from including classroom observations and investigations into other non-*CourseSource* OER sources and will provide important insights both for authors as they generate OER lessons as well as instructors as they make implementation decisions.

RQ2: To what extent do OER lessons help instructors incorporate V&C principles into their teaching?

Of all the V&C principles, the participants reported that the OER lessons were most helpful in providing opportunities for student-centered learning, particularly student discussions, group work, and assessment questions. This highlights a potential strength of OER journals like *CourseSource* in providing tangible, detailed lesson materials. This could be why so many participants used worksheets, assessment questions, and lab protocols in their courses, many without significant changes.

The lessons were also useful in supporting the incorporation of V&C core concepts and competencies, though to a lesser degree. We found that lesson materials tended to focus on particular concepts and competencies depending on the topic of the lesson, as exemplified by the lessons in the article subset (Figure 6). While there was generally good alignment with the intentions of the lesson authors, we did not find universal agreement between the users and authors (Table 3). For example, those who used the Cell lesson found that process of science was present and not the author-intended competency of modeling. This could suggest the need for continued discussions in the biology education community about how to define and actualize certain core concepts and competencies laid out in V&C, like the BioCore and BioSkills guides (Brownell et al., 2014; Clemmons et al., 2020).

Finally, only 34% (N = 47) of participants found the materials helpful in supporting DEIB. Given the utility and accessibility of OERs, these resources could be valuable in spreading teaching techniques that support diverse learners. However, the comparatively lower perceived helpfulness suggests that additional emphasis may need to be placed on DEIB by journals like *CourseSource* to best promote the sharing and adoption of inclusive teaching practices. The *CourseSource* article template contains an inclusive teaching section and suggests practices that can help a lesson reach diverse audiences (i.e., "provide examples of scientists from different backgrounds, encourage use of prior knowledge and experiences, or explicitly address access needs"). While this section has been refined over the years, our results suggest that further attention to the template, authors, and users might be needed for the lessons to have more substantial DEIB impacts.

In light of the teacher-curriculum framework, our results suggest that OER lessons represent a viable way for national calls, like those in V&C, to be translated into local teaching practices. When OER templates and guidelines explicitly require the content and approaches recommended by the broader education community, this prompts authors to shape their lessons accordingly, and the associated users view these materials as helpful to incorporating key principles. Our research plays an important role in facilitating the interactive component of the teacher-curriculum framework. Identifying disconnects between authors and users and highlighting areas that are not viewed as particularly helpful provides information back to those involved in the creation and distribution of OER lessons, who can refine their guidelines and approaches accordingly.

RQ3: In what ways do instructors perceive that their use of OER lessons has impacted their teaching?

Participants felt that their use of the OER lessons had an overall positive impact on their teaching, in particular on student learning and student engagement. Our analysis of the open-ended explanations indicated that the common sources of these positive impacts were due to the ways in which the content was addressed. This included the ways in which important disciplinary ideas and competencies were discussed and the incorporation of authentic practices.

Beyond the impacts on students, using these lessons also had a positive impact on the teachers themselves. Over a quarter of the instructors discussed how using these materials allowed them to try new teaching techniques, like group work or active learning, that they *had not used before*. Participants emphasized that they felt that they could take the pedagogical strategies they had learned from these lessons and apply them in their other teaching contexts. This highlights how there is an interactive relationship between the instructor and the lesson materials (Remillard, 1999, 2005). The instructor may make changes and adaptations to the materials, but at the same time the materials can shape how the instructor thinks about their broader teaching practices. Within the broader community of practice of biology educators (Wenger, 1998), these OER lessons represent the sharing of best practices between members of this community. This highlights the utility of OERs in supporting student-learning techniques, facilitating instructor professional development, and strengthening the broader community of practice.

Limitations

This investigation into the lessons published in only one OER journal (*CourseSource*) may not be representative of materials published in other OER journals, websites, and repositories. We decided to focus on a single journal so we could reduce variability across sources and refer to journal-specific conventions and structures in our survey questions. Future work is needed to understand the degree to which this work is generalizable to other biology OERs.

Conclusion

In this study, we found that lesson materials published in the OER journal *CourseSource* are often used by instructors directly in their courses without substantial changes. Instructors report using the materials as is because of the quality and alignment of the materials rather than due to other practical limitations that might prevent them from making changes. These results provide a more nuanced picture about how lessons are used by instructors, and further research is necessary to better understand how exactly these types of lesson materials are used in courses. Future research should also explore why instructors use OER materials and how contributions to the OER community are credited by academic reward systems. Exploring the internal and external motivators behind an instructor's decision to use or create such materials can inform strategies to encourage broader development of such resources.

Additionally, participants reported that each of the V&C principles (core concepts, core competencies, student-centered learning, and DEIB) were present in the lessons to varying extents. Of these, student-centered learning techniques (especially student discussions, group work, and assessments to gauge student understanding) were the most commonly identified helpful aspects of the lessons. This highlights one of the primary benefits of producing and using OER lessons: the potential for sharing student-centered activities with the broader biology education community. These results also identified potential areas for community growth, in particular the need for clarity about what certain core concepts and competencies mean and look like in practice (Branchaw et al., 2020; Brownell et al., 2014; Clemmons et al., 2020).

Finally, we found that these lessons had an overwhelmingly positive impact and practically no negative impact on these instructors' teaching. Furthermore, this impact was broader than just students' learning or engagement, but it was felt by the instructors too, especially in their potential adoption of student-centered learning techniques. This suggests that OERs could be an important way in which the biology education community can share best practices with one another. Taken together, these results show the utility of OER lesson materials for both students *and* instructors alike.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the University of Nebraska-Lincoln Institutional Review Board (IRB protocol 22214). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

KN: Writing – original draft, Writing – review and editing. KT: Writing – review and editing. SB: Writing – review and editing. MRS: Writing – review and editing. MKS: Writing – review and editing. BC: Writing – original draft, Writing – review and editing.

Funding

The authors declare that financial support was received for the research, authorship, and/or publication of this article. This material was based upon work supported by the National Science Foundation under grants DUE-2125990, DUE-2126110, and DUE-2125998.

Acknowledgments

This work would not have been possible without the survey feedback provided by members of Brian Couch's Lab, members of Michelle Smith's Lab, undergraduate research assistants Sanah Ahmed and Tiffany Adjei-Opong, and pilot participants. Additionally, we thank Drew LaMar for his assistance navigating *CourseSource*. Finally, we appreciate all of our survey participants for sharing their thoughts and experiences.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1485491/full#supplementary-material

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