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How Do Undergraduate Biology Instructors Engage With the Open Educational Resource Life Cycle?

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Open Educational Resources (OER) are widely used instructional materials that are freely available and promote equitable access. OER research at the undergraduate level largely focuses on measuring student experiences with using the low cost resources, and instructor awareness of resources and perceived barriers to use. Little is known about how instructors work with materials based on their unique teaching context. To explore how instructors engage with OER, we surveyed users of *CourseSource*, an open-access, peer-reviewed journal that publishes lessons primarily for undergraduate biology courses. We asked questions aligned with the OER life cycle, which is a framework that includes the phases: *Search*, *Evaluation*, *Adaptation*, *Use*, and *Share*. The results show that OER users come from a variety of institution types and positions, generally have positions that focus more on teaching than research, and use scientific teaching practices. To determine how instructors engage throughout the OER life cycle, we examined the frequency of survey responses. Notable trends include that instructors search and evaluate OER based on alignment to course needs, quality of the materials, and ease of implementation. In addition, instructors frequently modify the published materials for their classroom context and use them in a variety of course environments. The results of this work can help developers design current and future OER repositories to better coincide with undergraduate instructor needs and aid content producers in creating materials that encourage implementation by their colleagues.

Keywords: OER adoption, open educational repositories, post-secondary biology education, open educational resources, curriculum resources

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INTRODUCTION

Open educational resources (OER) are "teaching, learning and research materials in any medium—digital or otherwise—that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions" (UNESCO, 2021). These educational materials can take on a variety of forms (e.g., textbooks, images, animations, podcasts, assessment materials, learning activities, full courses such as Massive Online Open Courses or MOOCs) (Kanwar et al., 2011; Wiley et al., 2014). Their openness increases the access to quality educational materials for both instructors and students, and improves the efficiency of teaching preparation (Hilton and Wiley, 2011; Henderson and Ostashewski, 2018). Because OER are openly available, they can promote the diffusion of teaching knowledge while also reducing social inequities due to lack of access (Hylen, 2006). In describing the significance of OER, Blessinger and Bliss (2016, p. 11) note: "Designed for access, agency, ownership, participation, and experience, open education has the potential to become a great global equalizer, providing opportunity for people throughout the world to exercise this basic human right." Increased access to OER provides the opportunity to strengthen the interconnectedness of our global population and offers a socially inclusive way for people to engage in learning outside of higher education regardless of status or demographics (Blessinger and Bliss, 2016).

Estimates indicate that the OER movement has saved students over one billion dollars worldwide (Allen, 2018). Research around OER at the post-secondary level has largely focused on instructor awareness of resources and perceived barriers to use, and the broad impact on providing a high quality student experience at a reduced cost (Hassler et al., 2014; Cronin and MacLaren, 2018; Nusbaum et al., 2020; Spilovoy et al., 2020; Tillinghast et al., 2020). How undergraduate instructors engage with and modify materials for their unique teaching context remains an open question in need of further exploration (Ehlers, 2011; Santos-Hermosa et al., 2017).

Instructor OER engagement can be described in terms of a life cycle framework consisting of these phases: *Search*, *Evaluation*, *Adaptation*, *Use*, and *Share* (Clements and Pawlowski, 2012, adapted from Pawlowski and Zimmermann, 2007). The *Search* phase encompasses how instructors look for suitable resources. A recent survey in the United States indicates that 44% of undergraduate instructors are aware of OER with 26% of instructors who teach large-enrollment introductory courses reporting some level of use (Spilovoy et al., 2020). Pertinently, the most common barrier to OER use is a lack of instructor awareness of where to find resources, which can extend into confusion regarding Creative Commons licensing and permission for use of the resources (Belikov and Bodily, 2016; Lorenz and Preusse, 2018; Schuwer and Janssen, 2018). In the *Evaluation* phase, instructors locate a resource and decide whether it is trustworthy and suitable for their teaching context. Initial evaluations of a resource's quality and integrity are typically based on the reputation of the repository that hosts the resource, with resources tied to notable institutions (e.g., MIT OpenCourseWare) garnering higher levels of trust (Clements and Pawlowski, 2012). The *Adaptation* and *Use* phases capture modifications instructors make to existing resources that are aligned to their particular teaching contexts and how instructors are engaging with the materials to their unique teaching contexts. For these phases, the perceptions of others who implement OER are salient, including the importance of peer review and recommendations/user ratings (Recker et al., 2004; Clements and Pawlowski, 2012; Judith and Bull, 2016). University instructors often use OER to supplement their own course materials, such as providing additional readings or videos for students (Lesko, 2013; McKerlich et al., 2013; Bharti and Leonard, 2021). However, OER are rarely utilized in their original format; instructors often make adaptations to suit their personal context and enact changes that are reflective of their teaching approaches (Cardoso et al., 2019; Pulker and Kukulska-Hulme, 2020). Notably, OER active adopters (e.g., those who are looking for a ready-made resource) and those who are innovative in their re-use of OER are more likely to use constructivist teaching strategies (Pulker and Kukulska-Hulme, 2020). The final phase of the OER life cycle is *Share*, where the modified resource is shared back with the OER community for others to use (Atkins et al., 2007).

To expand knowledge of how undergraduate faculty are engaging with OER, we surveyed users of a journal that publishes instructional resources primarily for undergraduate biology called *CourseSource*[1] as a case study. *CourseSource* publishes OER lesson articles that employ evidence-based teaching strategies, are field-tested in undergraduate classrooms, provide all the necessary details and supporting materials (e.g., slides, assessment questions) to replicate the lesson, and include scientific teaching themes and reflections on student learning. The survey results allowed us to explore the following questions:

1. What are the characteristics (e.g., current position, connection to colleagues) of undergraduate biology instructors who are using OER?
2. How do undergraduate instructors engage in phases including *Search*, *Evaluation*, *Adaptation*, *Use*, and *Share* of the OER life cycle?

Insights on these questions can help developers design OER repositories to better coincide with instructor needs and aid content producers in creating materials that encourage implementation by their colleagues.

MATERIALS AND METHODS

Study Participants

To understand the characteristics of undergraduate biology instructors who are using OER, we surveyed *CourseSource* users as a case study. *CourseSource* is a peer-reviewed online journal that includes a community of over 10,000 users. The published lessons are aligned with the Vision and Change framework, which is a call to action to transform biology undergraduate education and outlines key concepts and competencies of the discipline (American Association for the Advancement of Science, 2011). Additionally, the Vision and Change framework emphasizes the use of scientific teaching, which encourages undergraduate instructors to approach teaching in a similar way to scientific research, namely using evidence to inform teaching decisions (Handelsman et al., 2004).

We emailed the survey to 1,955 individuals who logged into *CourseSource* from January to May 2021 and 173 individuals responded. We removed responses of those who did not consent ($n = 1$), did not complete the survey ($n = 21$), identified primarily working with K-12 students ($n = 16$), or had not used

[1] https://qubeshub.org/community/groups/coursesource/about

a *CourseSource* lesson in their courses (n = 4), leaving a dataset with a total of 131 responses from individuals who work at 123 institutions.

Survey Development and Structure

The survey underwent multiple rounds of revisions to improve face validity. The initial draft was shared with discipline-based education researchers (n = 15) and members of the *CourseSource* editorial board (n = 30). Following edits, the survey was piloted to undergraduate instructors who had participated in a *CourseSource* Writing Studio, a professional development program designed to help instructors publish their lessons as articles (n = 47). Finally, a revised version was vetted using online think-aloud interviews with undergraduate biology instructors who participated in *CourseSource* Writing Studios but had not previously taken the survey (n = 14). Participants were asked to respond to each question, describe their thinking, and state if any parts of the survey were unclear.

Survey Instruments

The final survey consisted of multiple instruments measuring: participant demographic information, access to teaching resources, scientific teaching practices, and engagement in the OER life cycle (**Supplementary Appendix 1**). The survey took ∼20 min to complete. The data generated from the survey were analyzed in Microsoft Excel using descriptive statistics and visualizations were created using Microsoft Excel and PowerPoint. The number of respondents for each of the data visualization figures is included in **Supplementary Appendix 2**.

Demographic Survey

Survey participant background information was captured with a variety of demographic questions. We determined the Carnegie Classification and Title IV, degree-granting minority-serving designation for each survey participant's current institution (Indiana University Center for Postsecondary Research, 2018; Rutgers Center for Minority Serving Institutions, 2021). The list of areas of expertise (e.g., molecular biology, genetics) was based on the way *CourseSource* articles are organized. Namely, they are organized around a typical set of undergraduate biology course offerings that align to common biological subdisciplines and professional society learning goals (CourseSource, 2021).

Access to Teaching Resources Survey

Survey participants were asked resource generator questions to better understand the social context around teaching and the use of OER. Resource generator questions are a way to measure the social capital of individuals, which captures how the social networks between individuals can provide access to resources such as knowledge or opportunities (Portes, 1998; Van Der Gaag and Snijders, 2005). Instructors who work in an environment that is supportive and actively engaging in active learning and/or using OER could provide support for the use of these practices (Lane and McAndrew, 2010; Andrews et al., 2016). In this survey, participants were asked about whether they have colleagues in their department, at their institution, and outside their institution who they can engage with about using active learning, sharing ideas about teaching, receiving advice about teaching, and using OER including with *CourseSource* materials.

Scientific Teaching Practices Survey

Scientific teaching practices were assessed using the Measurement Instrument for Scientific Teaching (MIST)-Short version (Durham et al., 2017). This instrument includes questions about the adoption of scientific teaching framework practices (Handelsman et al., 2004), which emphasize the use of evidence such as student data to inform teaching decisions (Couch et al., 2015; Durham et al., 2017). Survey participants were asked to complete the MIST-Short for the course in which they used *CourseSource* lessons most often.

Open Educational Resources Life Cycle Survey

To support content validity, we generated survey questions that align with the *Search*, *Evaluation*, *Adaptation*, *Use*, and *Share* phases of the OER life cycle framework (Clements and Pawlowski, 2012) using features from *CourseSource*. The survey primarily consisted of closed-response questions. Open-response questions were designed to help participants reflect on their answers and focus their subsequent survey choices on a particular instructional context (i.e., Think about ONE class in which you use CourseSource materials most often. Please describe the topics and objectives of this class in 1–2 sentences.). An analysis of the open-response questions is not the focus of this paper.

Questions about searching and using articles asked about specific filters from the journal such as the course topic (e.g., ecology), level (e.g., introductory), audience (e.g., life science major), and format (e.g., lecture). The filters also included pedagogical approaches (e.g., think-pair-share), types of assessments (e.g., homework), and scientific process skills (e.g., analyzing data). Finally, several survey terms are associated with larger learning frameworks such as the Bloom's cognitive level presented in the lesson (e.g., application and analysis) (Bloom, 1956), Principles of How People Learn (e.g., motivates students to learn material) (National Research Council, 2000), and Vision and Change core concepts (e.g., evolution) and competencies (e.g., ability to use quantitative reasoning) (American Association for the Advancement of Science, 2011).

RESULTS

Characteristics of Open Educational Resources Users

There is great diversity in the characteristics of undergraduate biology instructors who use OER. Survey participants came from a variety of degree-granting institutions (**Figure 1A**), were spread across many academic positions, and had a range of backgrounds in biology subdisciplines (**Figure 1B**). Only 9% of the survey participants worked at minority-serving institutions, which make up ∼14% of the institutions in the United States (Espinosa et al., 2017). The survey participants had high teaching loads; the

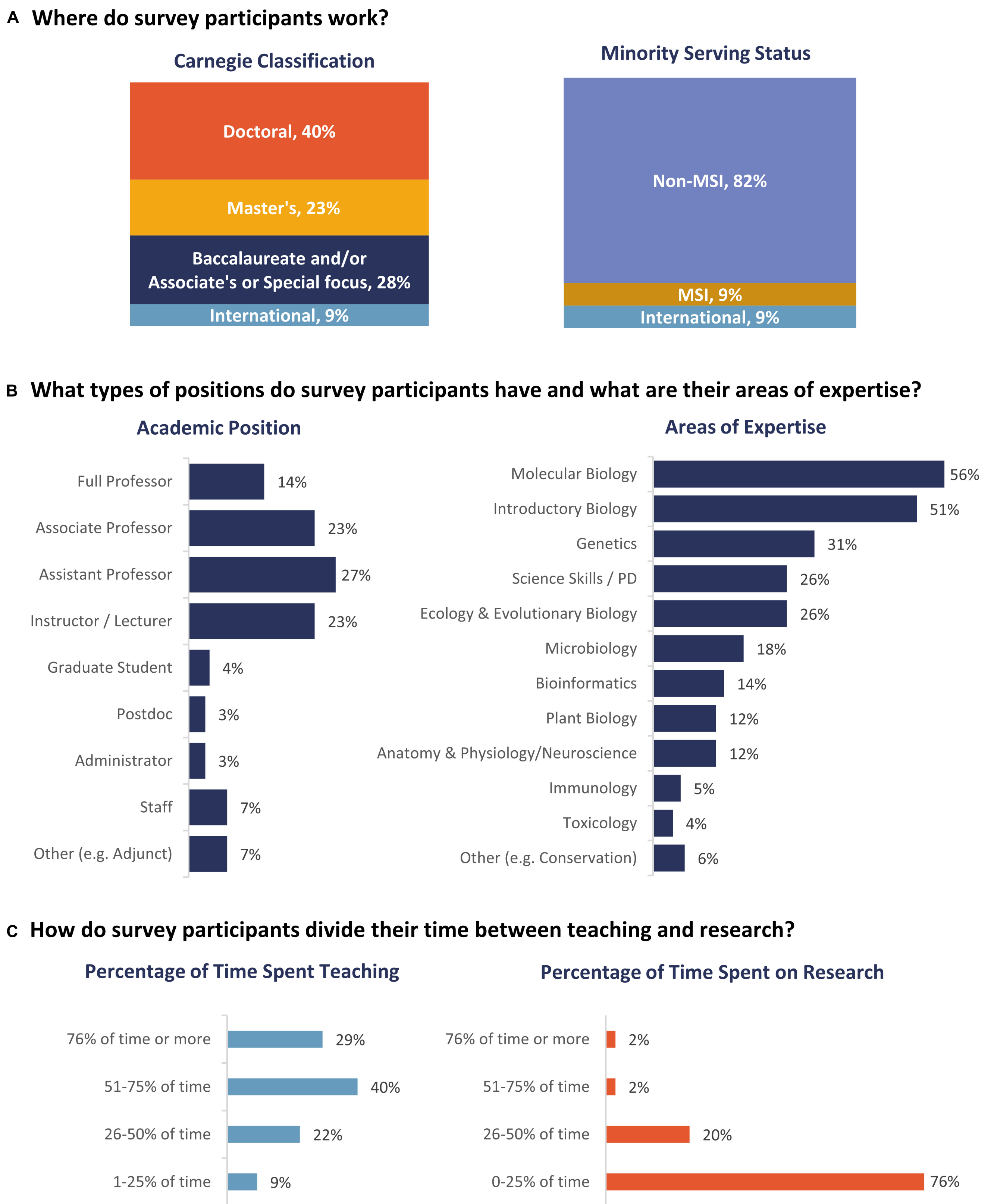

FIGURE 1 | Survey participants' demographic information based on: **(A)** Carnegie classification and Minority Serving Institution (MSI) type, **(B)** academic position and area of biological expertise, and **(C)** percentage of time spent on teaching and research. The abbreviation PD stands for Professional Development.

majority spent more than half their time teaching and less than a quarter of their time on research (**Figure 1C**).

To learn about the support context of survey participants, we asked resource generator questions about access to colleagues at the department, institution, and outside institution levels (**Figure 2**). More than 80% of the survey participants had someone in their department who they could talk with about using active learning, giving advice about teaching, and sharing effective ways to teach (**Figure 2A**). In addition ∼40% found this support at their institution, and ∼30% had this support outside their institution. The access to colleagues to talk to who use OER, both *CourseSource* and non-*CourseSource* materials, is lower (**Figure 2B**), especially at the institution and outside institution levels.

Because *CourseSource* is aligned with scientific teaching practices (Handelsman et al., 2004), we hypothesized that the survey participants would use these practices in their teaching. To measure the use of scientific teaching practices, survey participants answered the MIST-Short (Durham et al., 2017) about a course in which they use *CourseSource* lessons most often. The higher the MIST-Short score, the more likely a survey participant is using teaching practices aligned with scientific teaching themes. The overall MIST-Short scores ranged from 19.5 to 82.4 out of 100 points with a mean of 56.6 ± 1.12 SE. To put this mean in context, previous studies have shown that the mean scores of instructors who engaged in evidence-based teaching professional development range from 54 to 58 and the mean scores of instructors who did not range from 47 to 53 (Durham et al., 2017; Emery et al., 2020). When the MIST-Short scores are broken down by subcategory, the highest mean is in the Responsiveness subcategory (e.g., being aware when students do not understand a concept) and the lowest mean is in the Reflection subcategory (e.g., providing students opportunities to reflect on their problem solving or study habits) (**Figure 3**). The use of inclusive teaching practices varied the most.

Instructor Engagement in the Open Educational Resources Life Cycle

To explore how undergraduate biology instructors engage in the OER life cycle (Clements and Pawlowski, 2012), we asked about phases of this cycle using *CourseSource* as a case study. The first phase of the life cycle is *Search*. Survey participants were most likely to look for articles using the *CourseSource* search function and a list of course offerings which describe biology subdisciplines (e.g., genetics, evolution) (**Figure 4A**). The journal also provides search filters that users can select to find relevant articles (**Figure 4B**). The search filters survey participants most commonly selected include course topic, keyword text search, and course level (e.g., introductory). Educational frameworks such as Vision and Change (American Association for the Advancement of Science, 2011), Bloom's taxonomy level (Bloom, 1956), and scientific teaching principles (Handelsman et al., 2004) were used less often.

The next phase of the life cycle is *Evaluation* where instructors decide whether a particular resource is suitable for their teaching context and trustworthy (Clements and Pawlowski, 2012). Survey responses indicate that a variety of features were perceived to be very useful (**Figure 5**). Here the quality of the supporting materials (e.g., lecture slides, assessment questions) were the most useful followed by several features that aligned with the courses (alignment with course goals, ease to implement, and

Where do survey participants have access to colleagues?

A Active learning and teaching

I can engage with colleagues who…	Department	Institution	Outside my institution	No access to such a colleague
	…at the following resource levels			
Use active learning	82%	40%	35%	6%
Give advice on my teaching	84%	42%	32%	4%
Share ideas about effective ways to teach	87%	46%	39%	3%

B OER use

	Department	Institution	Outside my institution	No access to such a colleague
Use *CourseSource* materials	34%	10%	34%	32%
Use non-*CourseSource* OER	69%	22%	35%	9%

FIGURE 2 | Survey participants' access to colleagues at the department, institution, and outside institution levels based on **(A)** active learning and teaching advice and **(B)** OER use including *CourseSource* materials. The background color of the box is correlated with the frequency of choice.

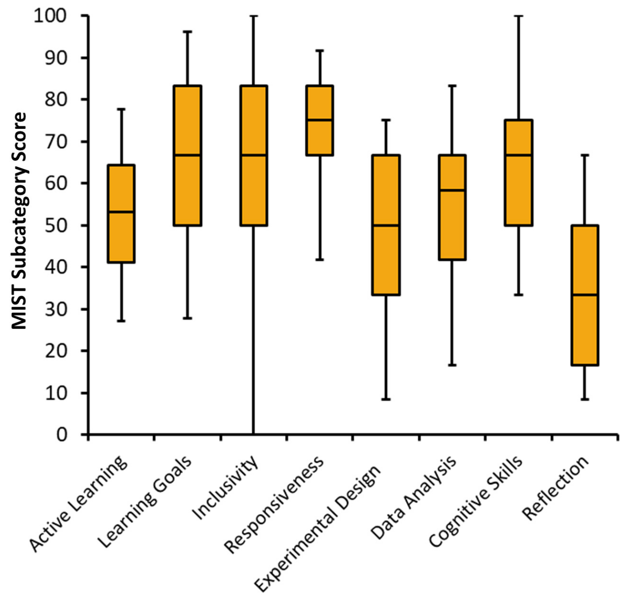

FIGURE 3 | Survey participants' teaching practices measured by the MIST-Short. Scores align with the eight subcategories of Scientific Teaching practices: Active-Learning Strategies (Active Learning), Learning Goal Use and Feedback (Learning Goals), Inclusivity, Responsiveness to Students (Responsiveness), Experimental Design and Communication (Experimental Design), Data Analysis and Interpretation (Data Analysis), Cognitive Skills, and Course and Self-Reflection (Reflection). Central bars represent median scores, boxes reflect interquartile range, and whiskers represent the 5th and 95th percentile values.

pedagogical approaches). Similar to the *Search* phase (**Figure 4**), frameworks such as Vision and Change (American Association for the Advancement of Science, 2011), Bloom's taxonomy level (Bloom, 1956), and Scientific Teaching principles (Handelsman et al., 2004) were rated less useful. Survey participants generally found the number of downloads, a proxy for how often other journal readers are exploring the lesson, to be less useful.

The third life cycle phase is *Adaptation* where instructors make changes that are aligned to their particular teaching context (Clements and Pawlowski, 2012). The majority (86%) of the survey participants indicated that they make modifications to the *CourseSource* lesson plan and timeline, which describes a recommended plan for implementing the lesson (**Figure 6A**). Almost all (99%) survey participants used the included supporting materials (e.g., lecture slides, assessment questions) either all or some of the time, including a variety of different types from worksheets to data spreadsheets (**Figure 6B**). Similar to the lesson plan and timeline, most of the survey participants (73%) tend to modify the supporting materials.

The next phase is *Use* which focuses on enactment of the resources in the classroom (Clements and Pawlowski, 2012). In this survey, questions largely explored how often the lessons are used. Most survey participants (60%) used *CourseSource* lessons 1–2 times per term (**Figure 7A**) in a variety of classroom settings (**Figure 7B**). One distinct pattern is that *CourseSource* lessons were most likely to be used in small (< 50 students) classrooms; 76% of the survey participants indicated that they used OER in small enrollment classrooms. Although some survey participants selected that they used *CourseSource* lessons in graduate courses, no instructors used the materials only at the graduate level.

Finally, the *Share* phase can be generally measured by asking how many survey participants share lessons through *CourseSource* publications. Only 28% of the survey participants had published an article in *CourseSource* and of those, 54% worked at doctoral granting institutions.

DISCUSSION

Our survey results showed that OER from CourseSource are useful to a diverse population of undergraduate biology instructors from a variety of institutions, position types, and subdiscipline backgrounds (**Figure 1**). What unites this group of survey participants is that they spend a higher percentage of their time on teaching when compared to research (**Figure 1C**), have access to colleagues who they can talk to about active learning and teaching (**Figure 2A**), and have MIST-Short scores similar to results from a subset of instructors who engaged in evidence-based teaching professional development (**Figure 3**; Durham et al., 2017; Emery et al., 2020). Now that an undergraduate biology OER community has been created, the next steps include expanding to a broader group of instructors who are less familiar with OER and evidence-based teaching practices.

A potential path forward could come from emulating the recent movement to increase evidenced-based teaching, which is the use of data to design instruction at the undergraduate level (Freeman et al., 2014; Wieman, 2014; Gross et al., 2015; Cavanagh et al., 2016; Driessen et al., 2020). For example, a survey about perceived supports (e.g., access to teaching resources, encouragement from colleagues) and barriers (e.g., perception of departmental and logistical constraints) to using evidence-based teaching was sent to undergraduate instructors who participated in relevant professional development opportunities (Bathgate et al., 2019). The results of this survey showed that perceived supports, rather than the removal of barriers, are most likely to be linked to implementation of evidence-based teaching practices. These supports come in many forms including revising tenure processes to include more of a focus on evidence-based teaching innovations, departmental support activities, professional development opportunities, and having access to experts (Pfund et al., 2009; Corbo et al., 2016; Shadle et al., 2017). Our results show that survey participants have more support for using active learning, giving advice on teaching, and sharing ideas about effective ways to teach, but have less support for engaging with colleagues who use OER especially at the institution and outside institution levels (**Figure 2**). Going forward, it will be important to focus on how to increase institutional and beyond institutional OER support for undergraduate instructors (Griffiths et al., 2020).

Undergraduate institutions can advocate for supporting instructor use of OER in several ways. One way is by providing instructors credit for sharing their OER with others during tenure and promotion decisions so they have a tangible recognition

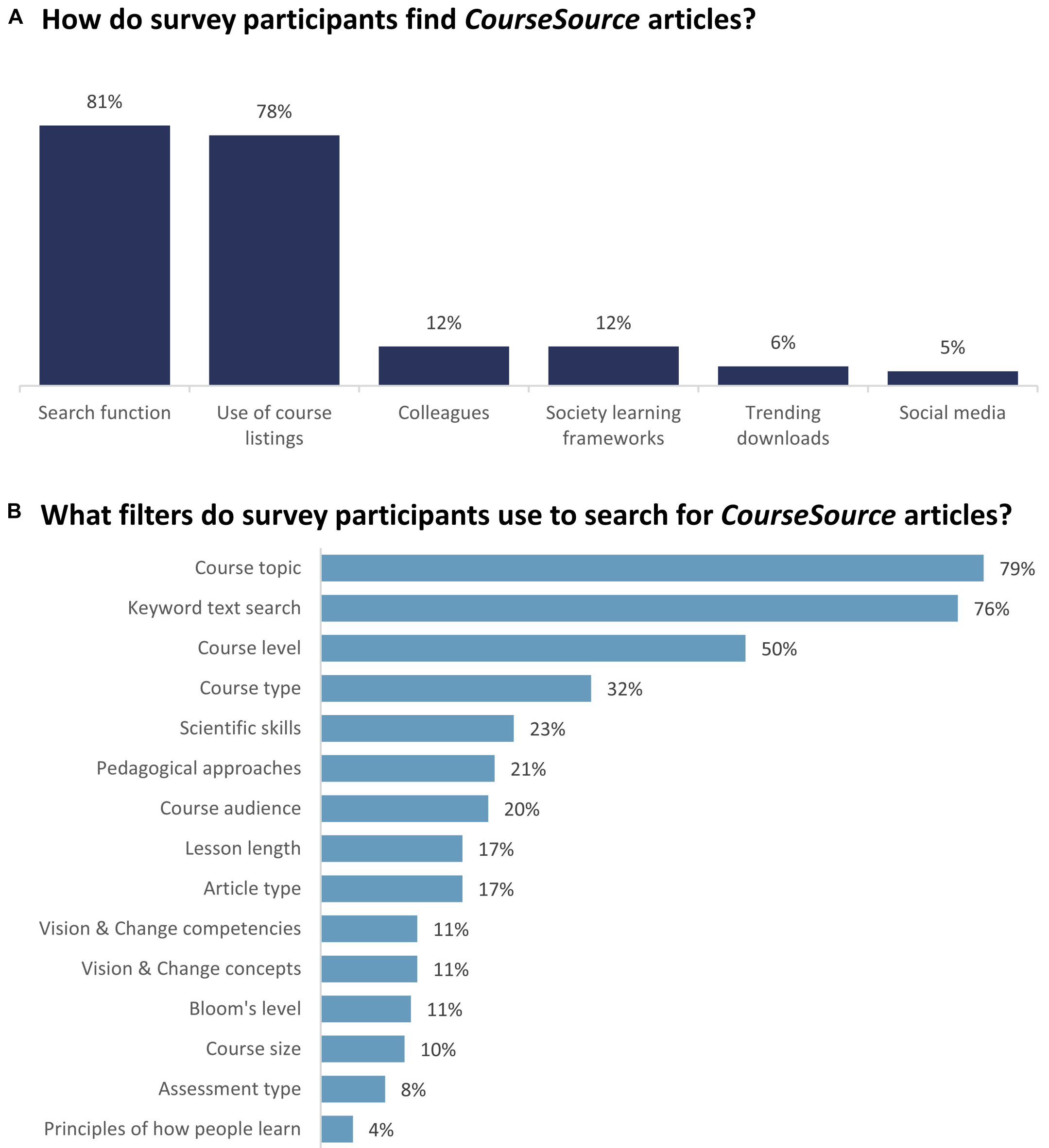

FIGURE 4 | Survey participants' *Search* engagement based on **(A)** how they find new articles and **(B)** which search filters they use. Filters represent what is available on the *CourseSource* website. A description of filters is included in "Materials and Methods" section.

of their work (Henderson and Dancy, 2007; Corbo et al., 2016). *CourseSource*, along with journals such as the *Journal of Microbiology* and *Biology Education* and *American Biology Teacher*, provide incentives in the form of a peer-reviewed journal citation that instructors can include on their CVs (Smith, 2018). Counting and highlighting these articles during tenure and promotion decisions sends a powerful message about the importance an institution places on developing and sharing innovative teaching materials. The institutions where the authors of this article work, Cornell University and the University of Maine, provide examples. Both institutions allow faculty to count articles that describe OER as part of their scholarly contributions and highlight the OER work of graduate students, postdocs, and faculty in news articles (e.g., UMaine News, 2018; Cornell Chronicle, 2020). Notably, only 28% of our survey participants had published in *CourseSource*, indicating that barriers to publication may exist or that faculty are unaware that publishing OER can result in tangible recognition. Going forward it is important to reach out to the undergraduate biology instructor community to advertise possible publication venues, demystify the manuscript preparation and submission process, and share ways instructors can highlight these contributions in tenure and promotion paperwork.

A second way institutions can support OER use is by creating cultures that value teaching and learning. Support for teaching as a community activity rather than one done in isolation, is shown

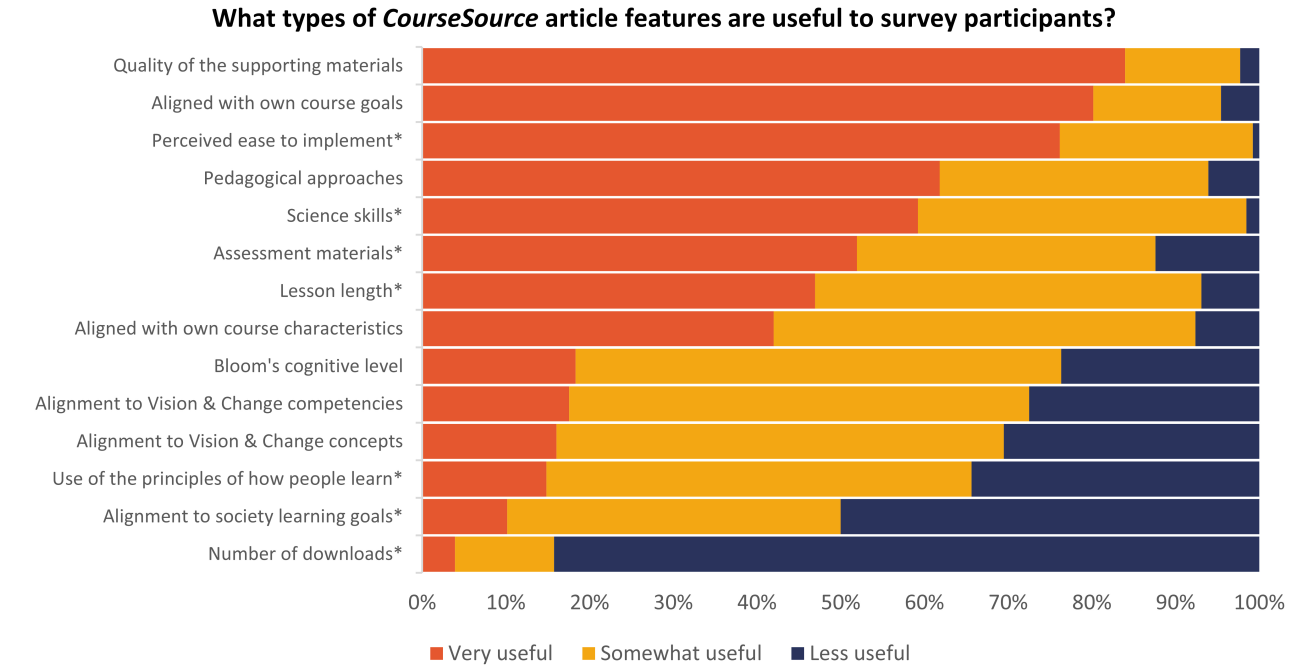

FIGURE 5 | Survey participants' *Evaluation* of resources. The bars illustrate the usefulness of different *CourseSource* lesson article features. Descriptions of the learning frameworks are in the "Materials and Methods" section. *Indicates that one or two survey participants did not select a level of usefulness for the particular article component.

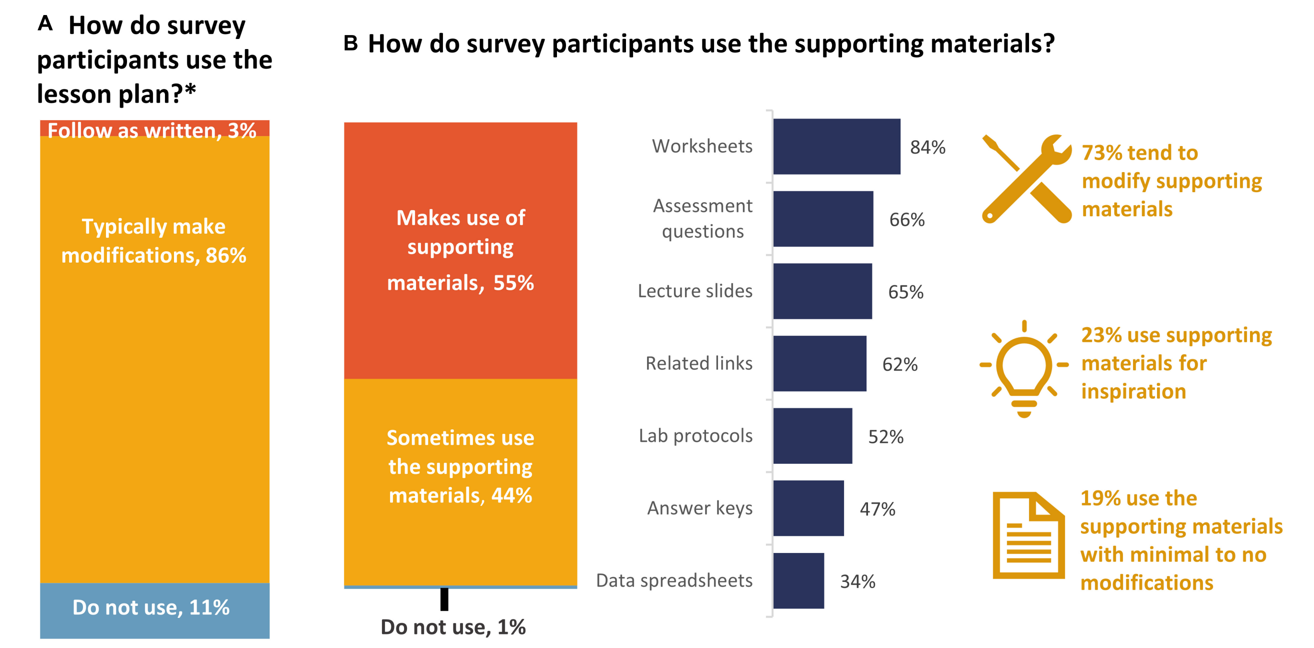

FIGURE 6 | Survey participants' *Adaption* of resources, particularly that of **(A)** the lesson plan and timeline and **(B)** the supporting materials. *Indicates that one or two survey participants did not answer this question.

to be critical for the motivation of instructors to use and share OER (Lane and McAndrew, 2010; Alevizou, 2012; Ehlers, 2014). To expand OER teaching and learning communities beyond what is shown in **Figure 2B** and especially to instructors who have higher research loads and might be less familiar with OER, instructors could partner with centers for teaching and learning and professional societies to engage in professional development opportunities focused on teaching with and sharing OER

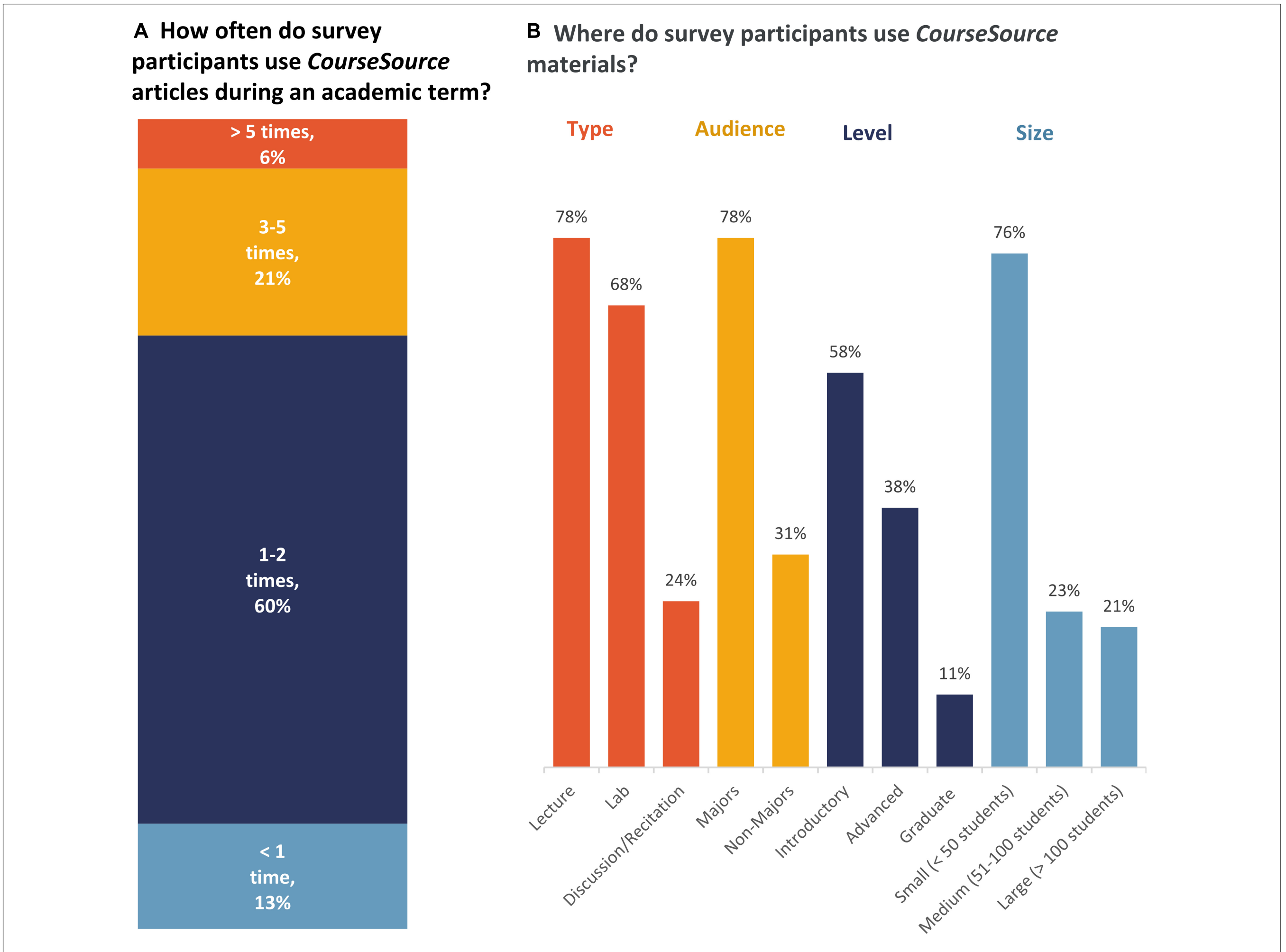

FIGURE 7 | Survey participants' *Use* of *CourseSource*. Captures **(A)** the number of times survey participants use *CourseSource* during an academic term and **(B)** types of courses for which survey participants use lessons.

(Ehlers, 2014; Otto, 2019). For example, the Center for Teaching and Learning at the University of Maine offers workshops where instructors can learn about finding and using OER with titles such as "Open Educational Resources: Learn about using free and licensed resources in lieu of textbooks." One additional source of support is librarians who can serve as liaisons to instructors who are looking for OER by using their knowledge of open access publishing (Anderson et al., 2017; Smith and Lee, 2017). Future work, which can draw on theories such as the diffusion of innovation (Borrego et al., 2010; Pashaeypoor et al., 2016), can explore how OER are shared and adopted by colleagues at the departmental, institutional, and beyond institution levels.

Supports can also be organized around the OER life cycle (Clements and Pawlowski, 2012, adapted from Pawlowski and Zimmermann, 2007). Using *CourseSource* as a case study, we found that the ability to use a search function and tie the resources to a specific course (e.g., ecology) are the most important search features (**Figure 4A**). When given the opportunity to use search filters, course-specific elements such as course topics and keywords are most often used (**Figure 4B**). Given that a lack of discoverability of relevant OER is a major barrier, these findings suggest that as OER repositories are being developed, it is important to include robust search functions and options that include relevant course elements (Belikov and Bodily, 2016).

After the *Search* phase, instructors enter into the *Evaluation* phase (Clements and Pawlowski, 2012). Previous work has shown that initial evaluations of a resource's quality and integrity are typically based on the reputation of the repository that hosts the resource; with resources tied to notable institutions garnering higher levels of trust (Clements and Pawlowski, 2012). Also, resources that use a peer-review process provides users with an increased assurance of quality and trustworthiness (Andrade et al., 2011; Clements and Pawlowski, 2012). Because we examined faculty evaluation of one peer-reviewed OER repository, we were able to gather more information about how instructors evaluate different materials within one source. Quality of the supporting materials (e.g., lecture slides, assessment questions), alignment to course goals, and perceived ease to implement are the most important features detected in our survey (**Figure 5**). These findings support the benefits of having a peer-review process that includes providing feedback on the quality of instructional materials.

For both the *Search* and *Evaluation* phases (Clements and Pawlowski, 2012), frameworks such as Vision and Change (American Association for the Advancement of Science, 2011), Bloom's cognitive levels (Bloom, 1956), and Principles of How People Learn (National Research Council, 2000), and alignment to biological society learning goals (e.g., Genetics Society of America, Ecological Society of America) were less useful than other features more closely tied to courses (e.g., alignment with course topics and goals) (**Figures 4**, **5**). While these broad frameworks, principals, and learning goals may not be as important within the use of one OER repository, they may be adding legitimacy and trustworthiness to the selection of the repository as each lesson is aligned with key concepts and competencies of its respective discipline (Clements and Pawlowski, 2012). Future work examining how and why undergraduate instructors select one OER repository such as *CourseSource* over another–including the importance of broad frameworks, principals, and society-supported learning goals in the selection process–will be important for better understanding potential roles of these features.

The *Adaptation* and *Use* phases capture modifications instructors make that are aligned to their particular teaching context and enactment of the lesson in the classroom (Clements and Pawlowski, 2012). Our survey results show that undergraduate biology instructors are likely to make modifications to the published OER supporting materials (**Figure 6**) and use them in a variety of classroom contexts (**Figure 7**). The finding that instructors are making adaptations to OER has been documented with undergraduate instructors from a variety of disciplines (Cardoso et al., 2019; Pulker and Kukulska-Hulme, 2020). While these collective results provide a starting point for understanding how instructors adapt and use resources, we currently know little about how instructors modify OER and whether those changes affect student learning. To date, only one study in biology education, which examined a group of faculty who collaborated on the development of a *CourseSource* lesson, explored variation in implementation (Pelletreau et al., 2018). This study found that even the collaborators varied strikingly in how they implemented the lesson in their own courses, ranging from using roughly 25 to 90% of class time in an active learning mode and seeing 35–95% correct answers on associated exam questions. Given that these instructors spent ample time working toward a common vision for the lesson, it is likely that users not involved in such a group have even broader variation in how they use a lesson.

Currently, instructors *Share* revised *CourseSource* materials by publishing them as additional articles in the same journal. For example, there is a *CourseSource* article about cell division and parthenogenesis designed for a college classroom that uses active learning (Wright, 2014), and a follow-up essay for how the materials were modified to teach it in a prison education classroom (Larson, 2018). In addition, there are several labs designed for in-person ecology courses focused on squirrel behavior (Connors et al., 2020; Duggan et al., 2020; Varner et al., 2020), and an essay about how these materials can be modified for remote teaching that was necessitated by the COVID-19 pandemic (Dizney et al., 2021). Having instructors publish their revised lessons as peer-reviewed articles encourages individuals to share back to the community and have a tangible outcome they can list on their CV (Smith, 2018). However, given that only 28% of the survey participants had published in *CourseSource* and the majority of these faculty came from doctoral-granting institutions, this process may be too large a hurdle for some. *CourseSource* is actively pursuing new formats for sharing including allowing authors to post updated versions that are also tagged to the original published lesson.

LIMITATIONS AND FUTURE DIRECTIONS

The results of this survey show that undergraduate biology instructors from a variety of institution types and positions are using OER, and in general these individuals spend a high percentage of their time teaching when compared to researching and have knowledge of scientific teaching principles. Focusing on one OER repository, *CourseSource*, as a case study, we find that instructors are engaging across the OER life cycle. In the *Search* and *Evaluation* phases, the ability to engage with features that align to the course specifics (e.g., course topic, alignment to course goals) and quality of the educational materials are most important. For the *Adaptation* and *Use* phases, instructors frequently modify the materials for their classroom context and use them in a variety of course environments. Notably, for the *Share* phase, it is rare for survey participants to publish OER by authoring *CourseSource* articles.

One of the limitations of our study is that the survey did not explore why undergraduate instructors search for OER. Future survey and interview questions could include: Are you choosing to use OER to learn new material, find new ideas for topics that are difficult to teach, and/or ensure equitable access to all students? A better understanding of answers to these questions will help content producers create materials that can be more efficiently integrated into classrooms. For example, content producers could be encouraged to add background information, to help instructors who are learning new material more quickly engage with the content.

Another limitation is that our survey questions on the *Use* phase focused on how often and where survey participants use *CourseSource,* rather than how instructors are engaging with the materials in their unique teaching contexts. To further explore the *Use* phase, we will build on work that examines the connections between teaching approaches and OER use (Pulker and Kukulska-Hulme, 2020) and conduct studies to examine how biology instructors change and enact OER in the classroom. We will document the changes instructors make through examining instructional artifacts (e.g., comparing published slides in the articles to slides used in class), interviewing instructors to learn more about the *Adaptation* and *Use* process, and conducting observations of instructors teaching the adapted OER. The Fidelity of Implementation framework (Century et al., 2010) will be used for these subsequent studies and we will characterize the revisions based on levels that have been established in previous curriculum studies: (1) minimal to no modifications of the OER, (2) partial adaptation of the OER, and (3) inspirational use of the OER where the majority of the lesson is created by the instructor (Brown, 2011; Papaevripidou et al., 2017; Stains and Vickrey, 2017).

We anticipate that our findings may be generalizable to undergraduate instructors in other fields. For example, studies in multiple fields show that undergraduate instructors often make OER adaptations to suit their personal context and enact changes that are reflective of their teaching approaches (Cardoso et al., 2019; Pulker and Kukulska-Hulme, 2020). To expand comparisons to include multiple phases in the OER life cycle, we encourage other fields to use and modify the survey questions in **Supplementary Appendix 1** to conduct similar studies of their communities. A comparison of the results will allow the broad OER field to determine what findings are generalizable and which are discipline specific. Also, articles published in peer-reviewed journals are one of several types of OER available to the community, so it also is important to explore how undergraduate instructors are using open textbooks, videos, and non-peer-reviewed resources. Here again, the survey questions in **Supplementary Appendix 1** can be modified to provide a starting point for studying how instructors are engaging in the OER life cycle with these additional resources.

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 human participants were reviewed and approved by the Institutional Review Board of Cornell University ID#1810008360. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

LS designed and validated the survey instrument, analyzed the data, prepared visualizations, prepared the original draft of the manuscript, and edited the manuscript. AH provided feedback on the survey, analyzed the data, prepared visualizations, and edited the manuscript. EV provided feedback on the survey, sent the survey to participants, and edited the manuscript. MS conceptualized the study, provided feedback on the survey, provided funding support, interpreted results, and edited the manuscript. All authors contributed to the conceptualization and design of the study in addition to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2022.835764/full#supplementary-material

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