AMERICAN SOCIETY FOR MICROBIOLOGY | JMBE Journal of Microbiology & Biology Education

| Tips and Tools

Open Resources for Biology Education (ORBE): a resource collection

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ABSTRACT In undergraduate life sciences education, open educational resources (OERs) increase accessibility and retention for students, reduce costs, and save instructors time and effort. Despite increasing awareness and utilization of these resources, OERs are not centrally located, and many undergraduate instructors describe challenges in locating relevant materials for use in their classes. To address this challenge, we have designed a resource collection (referred to as Open Resources for Biology Education, ORBE) with 89 unique resources that are primarily relevant to undergraduate life sciences education. To identify the resources in ORBE, we asked undergraduate life sciences instructors to list what OERs they use in their teaching and curated their responses. Here, we summarize the contents of the ORBE and describe how educators can use this resource as a tool to identify suitable materials to use in their classroom context. By highlighting the breadth of unique resources openly available for undergraduate biology education, we intend for the ORBE to increase instructors' awareness and use of OERs.

KEYWORDS open educational resources, OER, undergraduate biology education, teaching resources, life sciences

Educators often seek new ways to enhance student learning outcomes and promote educational accessibility. However, developing new teaching materials can take significant time and effort. Open educational resources (OERs) emerged as one way to facilitate the diffusion of knowledge. UNESCO (1) defines OERs as "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."

Within undergraduate life sciences education, OERs have been shown to promote accessibility, reduce costs for students and instructors, increase knowledge retention, and improve student success (2–4). The significance of OERs in enhancing student-teacher learning has been underscored by Vision and Change (V&C), a framework that describes core concepts and competencies that should be integrated into undergraduate biology programs and advocates for the use of student-centered pedagogical practices (5). The V&C report recommends that instructors create and disseminate student-centered teaching resources to improve undergraduate biology education.

Despite increasing use, availability, and awareness of OERs among higher education instructors (6), these resources are often dispersed across different repositories, journals, and websites. This diffusion can make it difficult for instructors to find OERs that align with their course learning objectives, with many instructors expressing a desire for a peer-reviewed repository of OER materials in their discipline (7).

We address this challenge by developing a resource collection of OERs that are currently being used in undergraduate biology courses, the Open Resources for Biology Education (ORBE; https://doi.org/10.6084/m9.figshare.25343107). By categorizing each

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The authors declare no conflict of interest.

Received 30 November 2023
Accepted 10 April 2024
Published 6 May 2024

resource based on topic, intended audience, and other relevant criteria, we aim to streamline the process of locating and utilizing OERs in life sciences education.

PROCEDURE

Using the ORBE

The ORBE is a resource collection designed to assist educators in locating new OERs to use in undergraduate biology courses. Containing 89 unique OERs, the ORBE was compiled by surveying undergraduate biology educators in 2020 (8) and 2021 about what OERs they use in their courses. For more details on how the ORBE was compiled, please refer to File S1.

Educators wishing to use the ORBE to identify new OERs can browse within any of the following categories (Table 1): resource name, URL, audience, topic area, resource description, presence of institutional support or institutional affiliation, level of no-cost access, and type of use/adaptation/redistribution policy. To aid in browsing this resource, users can download the spreadsheet and filter or search for key terms within each category using drop-down menus (accessed by clicking the gray triangle enclosed in a square icon to the right of each category name in the ORBE).

Safety issues

There are no safety issues associated with this study.

CONCLUSION

The final draft of the ORBE is hosted on figshare.com, an open-source online repository for research materials (https://doi.org/10.6084/m9.figshare.25343107). The websites listed in the ORBE serve several audiences, are often provided at completely no cost to users, largely have institutional support, and have a variety of use licenses (Fig. 1). Websites cover a wide range of biology subdisciplines including molecular biology, physiology, ecology, and evolution. The most listed resources are designed for undergraduate/K-16 audiences, indicating that undergraduate instructors are looking for materials designed specifically for their educational level. Institutional support is common; for example, 30 resources cite current or past support from the National Science Foundation and 31 cite a current or previous affiliation with a college or university.

The greatest variability is among use license types, which has the potential to be confusing for instructors who may want to use, modify, and share updated versions of materials. As such, we encourage OER authors to ensure that reuse, crediting, and adaptation policies for their materials are stated as clearly as possible. Creative Commons licenses offer one example of a particularly visible and user-friendly way for OER creators to license their work and communicate reuse policies to users (9; creativecommons.org). Creative Commons licenses have transparent language, a straightforward and widely used classification system, recognizable iconography, and useful links to support resources. These qualities benefit OER creators, who can easily apply licenses to their materials and retain the copyright of their work, and OER users, who can confidently understand licensing terms to appropriately use the materials.

Additionally, we encourage OER websites to support users by providing easily accessible information about the content they are hosting alongside costs and relevant details about reuse policies to support instructors using OERs more effectively in their teaching. Similarly, OER authors can support users by sharing as many relevant details as possible about their OER implementation context (e.g., intended audience, specific topic, teaching modality, class size, and learning goals). The more contextual details are specified, the easier it will be for instructors to identify appropriate OERs to adopt into their teaching practice.

Although we present the ORBE as a static document, we recognize that future revisions will be necessary. As the prevalence of OERs in undergraduate biology

TABLE 1 Open Resources for Biology Education user guide

ORBE category	Description	Sub-category
1. Resource name	Title of website	
2. URL	Link to the resource website	
3. Topic area	Description of the topic area(s) of education materials hosted on the website, as obtained from the homepage, "about me" page, or frequently asked questions (FAQ) page	Anatomy, Animal Behavior, Animal Science, Biochemistry, Biodiversity, Bioengineering, Bioinformatics, Biostatistics, Biotechnology, Botany, Cell Biology, Climate Science, Conservation, Disease, Ecology, Environmental Science, Evolution, Genetics, Genomics, Health/Healthcare, Human Health, Immunology, Marine Sciences, Medicine, Microbiology, Molecular Biology, Neuroscience, Oceanography, Physiology, Plant Sciences, Public Health, Quantitative Biology, Sustainability, Toxicology, Zoology
4. Resource description	Website description obtained from the language used on the website homepage, "about me" page, or FAQ page	
5. Audience	The intended audience of the educational materials provided	• **Undergraduate (or K-16)** = materials designed for teaching undergraduate students only or materials designed for undergraduate students and students in grades K-12 • **K-12** = materials designed for teaching students in Kindergarten through 12th grade • **Public** = materials designed for educating all ages or the general public
6. Institutional support/affiliation	Websites with noted past or present support from or affiliation with noncommercial educational or scientific institutions	• **Present**: resource cites affiliation with an educational or scientific institution (defined as one of the following: institution of higher education, governmental organization, scientific funding agency, museum, nonprofit research or educational organization, professional scientific society, or peer-reviewed academic journal) • **Absent**: resource does not cite affiliation or support from an educational or scientific institution. Resource is either a personal website or a website supported by a commercial entity
7. No-cost access	Details about the presence or absence of any financial restrictions to access educational materials on the website	• **Partial**: resource contains some educational materials that are freely accessible and others that are only accessible through an institutional or personal paid account • **Complete**: all educational materials that are freely accessible
8. Use/adaptation/redistribution policy	Details about restrictions on reuse/adaptation/redistribution of the educational materials on the website	• **Public domain**: allows for unlimited reuse without permission • **Creative Commons**: the public is granted permission through a Creative Commons license to use creative work under copyright law, with certain restrictions (e.g., attribution, noncommercial use) • **Custom-use license**: the public is granted permission through a custom limited-use license to use creative work under copyright law, with certain restrictions (e.g., attribution, noncommercial use) • **Unclear/unspecified**: a specific reuse policy is not identifiable on the website

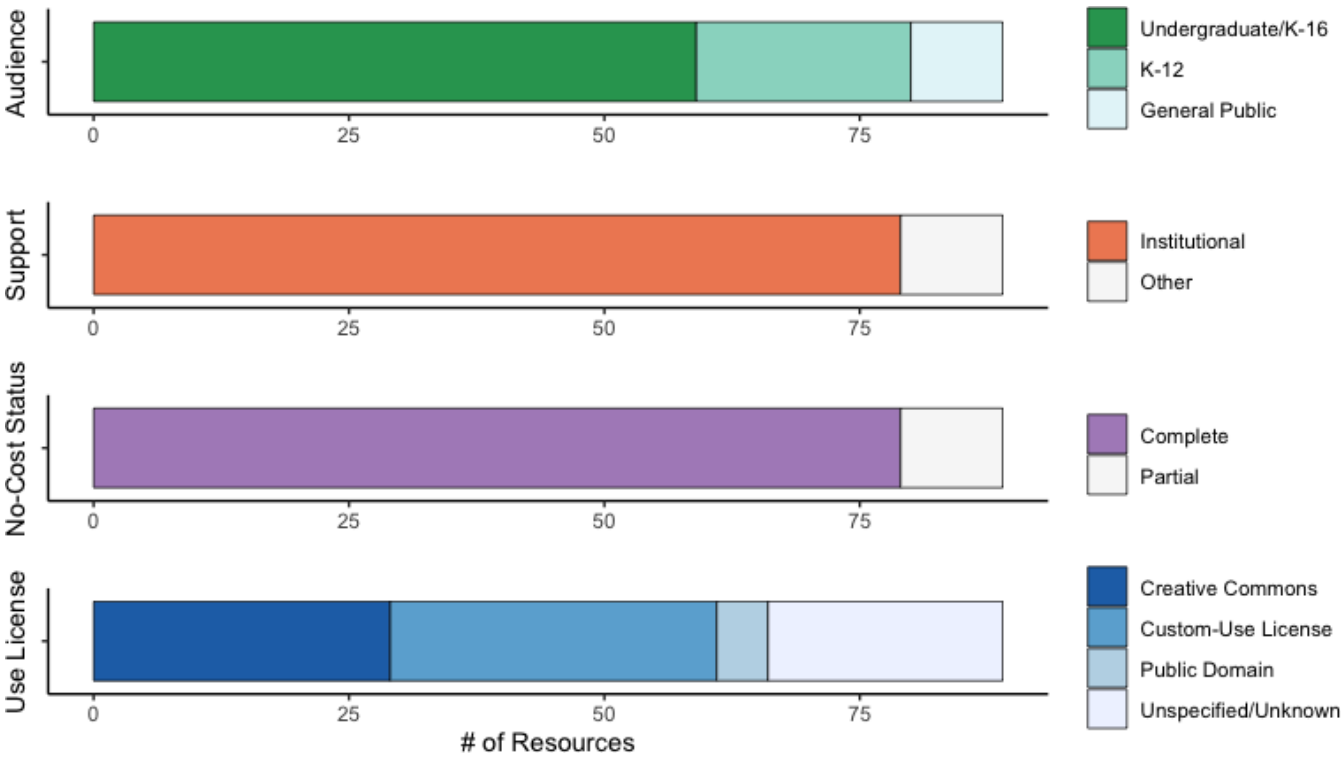

FIG 1 Overview of the intended audience, noncommercial institutional support, no-cost status, and use licensing of the 89 biology education resource websites listed in the ORBE.

education increases throughout the next decade, we see valuable opportunities for OER users to periodically compile similar resource collections. In addition to serving the community of biology educators by featuring new OERs, future OER collections can be compared with the ORBE to reflect how resources have changed over time. The ORBE, to our knowledge, is the first resource collection of its kind for undergraduate life sciences instructors to access a variety of OERs suitable for their courses. As the number and variety of OERs increase alongside growing awareness and use of OERs in higher education (6), ORBE represents the beginning of a needed community effort toward the management and dissemination of OERs. We hope that increased awareness and use of the breadth of resources available will result in increased usage and development of OERs in undergraduate life science courses.

ACKNOWLEDGMENTS

The authors wish to thank the Cornell Discipline Based Education Research group and anonymous reviewers for their thoughtful comments on the manuscript.

This work is supported by National Science Foundation grants DUE-1725130, 1917387, 2044189, 2043996, 2044118, 2125990, 2126110, and 2125998.

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ADDITIONAL FILES

The following material is available online.

Supplemental Material

File S1 (jmbe00203-23-s0001.pdf). Supplemental Materials & Methods (details about the creation of the ORBE, with additional information about how ORBE resources were identified via surveys and how OER status and additional details were ascertained for each resource).

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