REVIEW

Introducing BRAINOER: The Behavioral Research and Interdisciplinary Neuroscience Open Educational Repository

Amber L. Harris Bozer[1], Nichol A. Civitello[1,2], Elizabeth Dunn Rawlings[3], and Lesley F. Leach[4,5]
[1]Department of Neuroscience, Tarleton State University, Stephenville, TX 76401; [2]Department of Psychological Sciences, Tarleton State University, Stephenville, TX 76401; [3]Department of Information Science, University of North Texas, Denton, TX 76207; [4]Center for Educational Excellence, Tarleton State University, Stephenville, TX 76401; [5]Department of Educational Leadership and Technology, Tarleton State University, Stephenville, TX 76401.
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Foundational textbooks for neuroscience courses can be cost-prohibitive for students and may omit recent advances in the field. Therefore, an Open Educational Resource (OER) repository was curated using existing OER materials for use in behavioral neuroscience and physiology courses. The Behavioral Research and Interdisciplinary Neuroscience Open Educational Repository (BRAINOER) contains 9 modules that include the following foundational topics: (1) The Brain and Nervous System, (2) Neurons, (3) The Endocrine System, (4) Neurotransmitters and Psychopharmacology, (5) Motor Processing, (6) Advanced Brain Functions, (7) Sensation and Perception, (8) Genetics and Evolution, (9) Research, Design, and Methods. Each module contains learning objectives in a checklist format, and modules are divided into basic and advanced content where appropriate. Because the repository is divided into content modules, the materials can be used as a full-curriculum or assigned on a module-by-module basis.

Key words: Open Educational Resources; OER; Affordable Course Materials; ACM; educational repository

Textbook costs can be a financial barrier to students in higher education. For many students, an inflated cost of required course materials can incite decisions such as: taking fewer courses, searching for alternative educational sources that may not be matched to the curriculum or create additional learning gaps or errors, dropping or withdrawing from courses, or simply choosing not to purchase expensive course materials and solely rely on lectures and other disseminated materials available from the course (Martin et. al., 2017). Affordable Course Materials (ACM) programs provide students and educators with the opportunity to access low or zero cost educational materials such as Open Educational Resources (OER). Various studies report that OER-adopting instructors experienced an increase in student learning and engagement (Tillinghast, 2020; Jaggars et al., 2022).

Importantly, OERs help to mitigate costs by providing materials for learning with limited restrictions on licensing, redistribution, and modification (Leussis, 2022). These materials, which are available in a variety of media formats, may be accessed, shared, modified, and redistributed freely without cost. Open-access materials are distinct from other free materials in that they are freely customizable and may be adapted and modified to fit the needs of the user (Leussis, 2022). The purpose of OERs is to increase availability and universal access of information to a variety of learners without the barriers of cost (United Nations Educational, Scientific and Cultural Organization, n.d.).

Regarding the Cost, Outcomes, Use, and Perceptions (COUP) of OER, several studies have concluded that the cost-saving implications of replacing expensive textbooks with OER provides significant benefits to students, both financially and educationally (Bliss et al., 2013; Hilton III et al., 2014; Fischer et al., 2015; Watson et al., 2017). Aside from improving student learning, achievements, and success (McGreal, 2013; Dichev et al., 2015; Ashadevi & Muthamil Selvi, 2017), incorporating OER into courses can promote a positive educational "snowball effect" of reducing (and in some cases eliminating) the inequality of access to course materials among students from different socioeconomic backgrounds as well as increasing student engagement during and retention in these classes (Choi & Carpenter, 2017). OER materials for neuroscience can also be paired with open-source software, hardware, and data to offer exciting experiential and applied learning experiences, which addresses gaps in equity across institutions (Chagas et al., 2023).

Students using OER materials may even prefer OER textbooks as opposed to traditional course textbooks (Choi & Carpenter, 2017; Kinskey, King, & Lewis Miller, 2018; Cozart, Horan, & Frome, 2021; Angelopoulou et al., 2022). This is primarily due to cost savings, but the benefits of OERs also include factors such as portability, convenience, quality, engagement, and ease of access (Angelopoulou et al., 2022). A study by Angelopoulou et al. (2022) indicated that (a) students who were characterized as having more motivation to learn perceived the OER textbooks as a better resource than their traditional counterparts, (b) students were more likely to register for a future course with OER material and c) a majority of students like the OER material more than a traditional textbook.

Considering the Use of OER and ACM in STEM Fields

As previously stated, costly course materials contribute to students making educational decisions in the form of detrimental shortcuts (e.g., taking fewer courses, dropping courses, foregoing required course materials). Given there is already an established amount of pressure put on students attempting to achieve a higher education degree (especially those within the STEM fields), arguably, incorporating OER in meaningful ways to mitigate student financial and access barriers can serve to reduce, at least in part, the academic achievement gap and additional obstacles that might be otherwise associated with the continued use of costly textbooks.

Further, OERs provide a variety of opportunities for education in STEM fields. One of the advantages is that the customizable features of OERs allow them to be updated to include the latest research; thereby, preventing additional gaps in learning inherent to the timeline in which textbooks take to be reviewed and published against concurrent knowledge (often times equating to a 5-year to 10-year lag). Thus, OERs can also be adapted to meet the unique needs of each learner or course, whilst also providing more interactive learning experiences, and sustaining student engagement in the learning materials (Wynants & Dennis, 2022).

Postsecondary institutions have been struggling with a decrease in enrollment in recent years, which is expected to continue. The STEM fields have not been immune to this trend (Chen et al., 2018). The initial years of higher-educational academic programs are especially critical for determining whether a student will continue with their educational goals, with research suggesting that more than 60% of undergraduate student attrition in STEM majors takes place within the first or second year of the academic programs (Chen et al., 2018). The number of neuroscience undergraduate programs in the United States, however, is growing and the number of graduates of neuroscience programs contributes substantially to the number of graduates of the life sciences (Ramos, 2016).

OER and ACM Materials Specific to Neuroscience

There are a number of existing Open Educational Resources for students of neuroscience, which were neatly summarized by Leussis (2022). Earlier examples of open access materials in the field of neuroscience include Educational Resources in Neuroscience (ERIN), and the Society for Neuroscience's (SfN's) web portal for higher education which was funded by a grant from the National Science Foundation (Olivo et al., 2015). OER repositories can be fully compiled using existing OER material, as in the case of the proposed Behavioral Research And Interdisciplinary Neuroscience Open Educational Repository (BRAINOER, 2022).

The content of each of the BRAINOER modules summarized herein contains some of these existing resources, with the addition of a myriad of other OERs. The BRAINOER is distinct from other online textbooks such as Austin Lim's Open Neuroscience Initiative (https://www.austinlim.com/open-neuroscience-initiative) in that the BRAINOER draws from a variety of open access resources rather than deriving from one primary author. It is also distinct from collaborative resources such as the ERiN portal (Olivo et al., 2015), Neuroscience in the Time of Corona (https://docs.google.com/document/d/1ChuOfTnKwAQqIKcaosrmAtygtxGAfb4MS3M6VMth_Uo/edit?usp=sharing) and Covid Teaching and Parenting Resources (https://docs.google.com/spreadsheets/d/1oVIksseJnmJiDP52h0OeJiM6IXTOMiebAVci3BBxrEU/edit#gid=1372964145) in its curation of materials into topics/study tracks that will be ideal for use in undergraduate neuroscience courses.

The BRAINOER repository can be utilized for a free-standing course, or as a more optional selection of modules to serve as complementary or ancillary material to an existing course framework. The core existing materials that were synthesized to create the BRAINOER repository primarily include content from:

- NOBA (https://nobaproject.com/browse-content); Biswas-Diener & Diener (Eds, 2014)
- 2-MinuteNeuroscience (https://www.youtube.com/playlist?list=PLNZqyJnsvdMqFNFyHvMFrFnlXLosnwwB_)
- Foundations of Neuroscience (https://openbooks.lib.msu.edu/neuroscience/front-matter/introduction/); Henley (2021)
- Anatomy and Physiology 2E (https://openstax.org/details/books/anatomy-and-physiology-2e); Betts et al. (2022)
- Neuroscience: Canadian 2nd Edition (https://ecampusontario.pressbooks.pub/neurosciencecdn2/); Ju (2020)
- Ted Talks (https://www.ted.com/talks)
- Neuroscience Online (https://nba.uth.tmc.edu/neuroscience/); Byrne et al. (1997)
- Functional Neuroanatomy (https://www.neuroanatomy.ca/); UBC; Krebs, Fejtek, et al. (2024)

The BRAINOER was created uniquely to address the need for OER materials in commonly taught behavioral neuroscience and physiology courses specifically but could be useful for other courses.

BRAINOER MODULES

The BRAINOER can be accessed at this link: (http://bit.ly/40t7QG2) and QR code:

Figure 1. QR Code for BRAINOER

The BRAINOER is organized into 9 modules, and each module contains a learning checklist for objectives that complement the material located within that module.

1. The Brain and Nervous System

The module titled "The Brain and Nervous System" is divided into four sections: "The Brain: The Basics," "The Brain: Advanced," The Nervous System: The Basics," and "The Nervous System: Advanced." This structure allows the instructor to assign sections based on the course level. For example, an Introduction to Neuroscience course might cover the basic sections, where an upper level or graduate course might cover both the basic and advanced sections using a scaffolded approach that can be particularly useful for interdisciplinary programs.

In the section "The Brain: The Basics," students interact with materials that cover the brain structure, anatomy, and function at a basic level, footage of the implications of split-brain procedures, the left brain/right brain myth, functional neuroanatomy, and common methods for studying the brain. In the Advanced section, students are presented with more in-depth materials about the brain, including coverings of the brain, ventricles, cerebrospinal fluid, mechanisms of stroke, brain injury, implications of brain damage, and a Ted Talk by Dr. Jill Bolte Taylor about her "stroke of insight." "The Nervous System: The Basics" section contains an introductory view of the divisions of the nervous system and the functions. The Advanced section contains a more detailed overview of the nervous system, brain divisions and functions, and spinal cord structure.

2. Neurons

The "Neurons" module is divided into three sections: "Neurons: The Basics," "Test Your Knowledge," and "Neurons: Advanced." The basics section contains an introduction to glial cells, neurons, neuronal structure, neuronal function, membrane potentials, diffusion, ion movement, gradients, the equilibrium potential, the action potential, and summation. The section also contains a link to archive film of the giant squid axon and a link to an introductory chapter about neurophysiology. The "Test Your Knowledge" section includes links to digital games such as "Signal" (Kaur, 2021). The gamification components are meant to serve as engaging resources for students as they refine their knowledge of neural communication. The Advanced section contains more in-depth content about the components of the neuron, cell types, glial cell functions and types, features of the action potential, intracellular recording, Galvani's work on electrical signaling, and an example of cell specificity.

3. The Endocrine System

The "Endocrine System" module contains an introductory level view of behavioral endocrinology and neuroendocrinology including hormones (steroid and peptide), hormone receptors, key cortical areas, the Hypothalamic-Pituitary-Adrenal (HPA) axis, stress, examples of hormone-behavior interactions, and examples from Dr. Robert Sapolsky's work in this area.

4. Neurotransmitters and Psychopharmacology

The "Neurotransmitters and Psychopharmacology" module is separated into two sections. The Neurotransmitter section consists of content about synapses, synapse locations, small molecule neurotransmitters, peptide neurotransmitters, common neurotransmitters and their functions, and the stages of neurotransmitter release. The Neuropsychopharmacology section contains a brief introduction to neuropharmacology, pharmacokinetics, antagonists vs. agonists, routes of administration, the reward system, drugs and toxins, Mouse Party (a game for understanding the effects of drugs at the neurotransmitter level), an example of drug interactions, and footage of classic studies in rodent self-stimulation.

5. Motor Processing

The "Motor Processing" module consists of information about the levels of the motor control (spinal cord, brain stem, motor and premotor cortices, supplementary motor cortices, the association cortices, the basal ganglia, and cerebellum), processing of motor control (alpha motor neurons, motor units, ventral horn, the neuromuscular junction, proprioception, Parkinson's disease, and L-DOPA Responsive Dystonia). There is also a section on optional advanced content covering motor system disorders, more on the neuromuscular junction, and descending motor pathways.

6. Advanced Brain Functions

The "Advanced Brain Functions" module is divided into three sections. The first section consists of an introductory view of intelligence (including intelligence theorists and the Flynn effect), consciousness (including cortical blindness, neural synchronization, the Rubber Hand Illusion), and emotions (affective neuroscience, neural mechanisms, and culture). The second section contains an overview of the basics of language (brain areas involved in language, function, and implications of damage), and animal studies of language processing in two species. The learning and memory section contains information on learning and conditioning such as Classical Conditioning and elements, elements of Operant Conditioning, Thorndike's Law of Effect, footage of rat basketball, taste aversion, Pigeon guided missiles, and observational learning. The section also contains information on learning and memory including the neural mechanisms of memory, and the case of H.M. The additional content module contains more advanced content about learning and memory, with added content about judgment and decision making, executive processing, and language studies in gorillas.

7. Sensation and Perception

The "Sensation and Perception" module contains five sections, and an additional content area. The "Introduction to Sensation and Perception" section consists of basic content covering sensation, transduction, perception, thresholds, and sensory adaptation. There is a table activity that allows students to identify the stimuli, receptors, sensory organs, cortical areas, and processes for the senses touch and pain, hearing, vision, taste, and smell. The "Touch and Pain" section consists of content covering the basics of touch, somatosensation, pain, nociception, the homunculus, roles of receptors and nerve fibers, placebo analgesia, congenital analgesia, and phantom limb pain. This section also includes two researcher features. The "Vision" section contains information on the components of vision and their roles (cornea, iris, lens, retina, receptors, cortical areas, etc.), transduction, and examples of irregularities or damage (agnosia, synesthesia, Charles Bonnet Syndrome). The "Hearing" section covers amplitude, pitch, timbre, components of hearing (pinna, cochlea, malleus, incus, stapes, cortical areas, etc.) and the vision process. The "Taste (Gustation) and Smell (Olfaction)" section consists of an overview of gustation, including the stimuli, receptors (taste-buds), and processes, and examples of irregularities (miracle berries and taste aversion). This section also includes an overview of olfaction including associated stimuli (odorants), receptors (olfactory receptors), organs (olfactory epithelium), and processes (retronasal vs. orthonasal olfaction), and examples of irregularities (anosmia). The "Additional Content" section contains more advanced content pertaining to somatosensation and multimodal perception.

8. Genetics and Evolution

The eighth module covers "Genetics and Evolution." This module prompts students to define evolution, understand adaptation, sexual selection, epigenetics, phenotypes, interactions between the environment and the genome (The Dutch Hunger Winter and lactase persistence), and evolution of the nervous system.

9. Research, Design, and Methods

In the final "Research Design" section, the content contains material on correlational designs (correlation coefficients, negative vs. positive correlations, correlation, and causation), experimental designs (independent variables, dependent variables, extraneous variables, random assignments, confounds, and participant demands), quasi-experimental designs, longitudinal designs, and survey studies. Additional content covers replication, the replication crisis, and thinking like a scientist (induction, avoiding pseudoscience, anecdotal evidence, and scientific theory).

DISCUSSION

The BRAINOER aims to be a part of the movement within higher-educational institutions toward expanding OER and ACM offerings to facilitate student success. As such, the BRAINOER is an attractive resource for neuroscience courses, containing modules that touch upon the brain and nervous system, neurons, the endocrine system, neurotransmitters and psychopharmacology, motor processing, advanced brain functions, sensation and perception, genetics and evolution, and research design and methods.

Incorporation of materials such as the BRAINOER for neuroscience and physiology courses provides several advantages. First, the BRAINOER allows for expanded access to student learning in that students have the opportunity to access the desired material anywhere at any time—repeatedly. Second, it allows for the information to be circulated quickly, which is a desirable characteristic when compared to information published in textbooks or journal articles that can take up to months or even years before they become available to the general public. Third, the method of hosting materials on a website provides the opportunity to continually improve the resources given that direct editing and incorporation of feedback can happen instantaneously. Fourth, the BRAINOER can also be used to enhance regular course content given that the information provided is a collection of other multimedia materials, such as videos, diagrams, research articles, and various textbook information. Providing information in multiple formats helps to engage students and improve learning. Lastly, the BRAINOER carries the main advantage of being an affordable supplement (or replacement) to expensive course textbooks. The use of OERs in neuroscience coursework has been relatively underexplored in comparison with traditional teaching materials, and the BRAINOER materials are available for instructors of neuroscience to utilize, adapt, and consider as one more example of OER that can address financial and educational gaps.

Future additions to the BRAINOER materials will include an Animal Behavior module, a module on famous scientists, and a new stand-alone OER repository specific to somatosensory processing and pain (PAINOER).

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Please address correspondence to: Dr. Amber Harris Bozer, Department of Neuroscience, Box T-0820, Tarleton State University, Stephenville, Texas, 76402. Email: bozer@tarleton.edu