The Journal of Undergraduate Neuroscience Education (JUNE), Winter 2024, 22(2):A90-A98

ARTICLE

A Case for the Use of Open Data as a Tool to Incorporate Socioscientific Topics into Neuroscience Education

Madison Meuler and Kaitlyn Casimo
Allen Institute, Seattle, WA, 98109.
https://doi.org/10.59390/YKOU9984

Education scholars have called for an increased focus on developing curricula based on culturally relevant pedagogy (Ladson-Billings, 1995). A key tenet of Ladson-Billings' (1995; 2014) theory of culturally relevant pedagogy is the development of students' sociopolitical consciousness, whereby students feel empowered and encouraged to evaluate and solve real-world interdisciplinary problems. Here, we propose that open science datasets could serve as a valuable tool for neuroscience educators to foster their students' sociopolitical consciousness.

Using the open data available through the Seattle Alzheimer's Disease Brain Cell Atlas (SEA-AD) as a case study, this article will explore how open science can be leveraged as a tool to encourage socioscientific thinking amongst neuroscience students. We overview a collection of lessons created by the Allen Institute's Education & Engagement team that provides a scaffolded exploration of an open science resource through a socioscientific lens. We supplement our discussion of the lessons with feedback from students who completed the lessons during a day-long workshop hosted at the Allen Institute in Seattle, WA. We conclude by reflecting on the future role this type of interdisciplinary, open science-based approach to curricula could have across neuroscience education more broadly.

Key words: open science; open data; socioscientific issues (SSI); sociopolitical consciousness; culturally-relevant pedagogy; Alzheimer's Disease (AD); transcriptomic data

Recent research in science education has underscored the importance of developing culturally relevant (Ladson-Billings, 1995; 2014) and culturally sustaining (Paris & Alim, 2017) curricula. Ladson-Billings originally proposed the concept of culturally relevant pedagogy in 1995, explaining that successful teachers are able to foster among students (1) academic success, (2) cultural competence, and (3) a sociopolitical consciousness. In 2014, Ladson-Billings highlighted the importance of pedagogy that extends beyond the culturally relevant framework and instead strives to be what Paris & Alim (2017) call culturally sustaining. Paris & Alim (2017) define culturally sustaining pedagogy as a method of structuring education in order to foster cultural pluralism rather than perpetuate a monocultural society.

The concept of culturally sustaining pedagogy is especially pertinent to STEM education, as Western science has long been criticized as a predominately white and predominately male discipline (NCSES, 2023). Given the monocultural history of Western science, science classrooms must be intentional about developing methods and strategies to strive towards Paris & Alim's (2012) ideal of cultural pluralism. One method science educators have used to implement culturally-sustaining pedagogy is to focus on developing a student's sociopolitical consciousness. Ladson-Billings (1995) defines a student's sociopolitical consciousness as a student's ability to apply what they have learned in the classroom to real-world interdisciplinary problems. The concept of the sociopolitical consciousness closely mirrors that of Freire (1970), who proposed the idea that education should foster a student's critical consciousness in order to empower them to see themselves as transformers of the world when they are faced with systemic social justice issues.

In order to foster students' sociopolitical consciousness (Ladson-Billings, 1995), or what Freire (1970) would call their critical consciousness, science education scholars have advocated for embedding socioscientific issues (SSI) and ideologically aware material into curricula (Costello et al., 2023). While some instructors, particularly at the K-12 level, have expressed hesitancy towards integrating socioscientific topics into their courses because they believe those topics fall under the jurisdiction of humanities classes rather than the sciences (Levinson, 2001), other scholars have argued for curricular integration (Skorton, 2018; 2019). Specifically at the undergraduate level, scholars have argued for the integration of ideologically aware material into postsecondary biology curricula, which is defined as including discussions of biases, stereotypes, and historical injustices within science classrooms in the hopes of creating inclusive and more transparent learning environments (Costello et al., 2023).

While including discussions of socioscientific issues and intersections between science and society was added as a core competency within *Vision and Change in Undergraduate Biology Education* (AAAS, 2011), educators still face several barriers in incorporating these topics within their classrooms. For example, recent research suggests that while undergraduate biology instructors see the value in incorporating such concepts into their class, they express hesitancy in doing so (Beatty et al., 2023). The most common reason cited for instructor hesitancy was a disciplinary content disconnect, where instructors felt as though the ideologically aware content did not naturally fit within their course's existing scientific content (Beatty et al., 2023).

Neuroscience and Socioscientific Issues

While much of this education research on ideologically aware material and socioscientific issues was conducted within general biology contexts, these findings hold several implications for neuroscience education specifically. Neuroethics is a burgeoning field (Illes & Bird, 2006) that is ripe with socioscientific topics for students to analyze and reflect upon. The history of science also contains numerous examples of scientific racism, biological determinism, and eugenics that are highly relevant to the field of neuroscience specifically (Gould, 1981). Scientific racism is also not a purely historical phenomenon, as it is still observable within modern neuroscience research, such as that focused on the neuroscience of violence and the 'neuroscience of race' (Rollins, 2021a; 2021b). Scholars have argued that moving toward an antiracist neuroscience requires discussions of sociohistorical investments within the field of neuroscience (Rollins, 2021a), which in and of itself is a socioscientific topic. In order to help neuroscience educators incorporate these discussions of socioscientific topics into their courses and avoid feelings of disciplinary content disconnect where the content appears discontinuous or forced within the larger course curriculum (Beatty et al., 2023), we propose the use of open data sets in neuroscience courses. Open data sets, particularly those generated from human subjects research, could provide students with a unique opportunity to strengthen their data analysis and critical thinking skills while also strengthening their socioscientific thinking.

Open Data in the Neuroscience Classroom

Open science is a practice in which data, protocols, materials, and other important pieces of research information are shared openly for others to access. The open science movement has garnered increasing momentum over the past few decades, with the President's Office of Science and Technology Policy releasing a memorandum in August 2022 calling for open science practices to lower "barriers of access to science for all of America" (Nelson, 2022). While open science holds many potential benefits for researchers and other potential users (de Vries et al., 2022; Wilkinson et al., 2016; Allen & Mehler, 2019), open science also has several potential benefits for educators and students (Casimo, 2023).

Previous studies have shown that the integration of research experiences in the classroom, such as through Inclusive Research Education Communities (Hanauer et al., 2017), or Course-Based Undergraduate Research Experiences (Bangera & Brownell, 2017; Duboue, Kowalko, & Keene, 2022) has several promising outcomes. For example, students who engage in classroom-based research experiences have shown increased persistence within STEM fields relative to their peers who do not participate in classroom-based research (Hanauer et al., 2017). The ability of research experience to encourage persistence and retention in STEM has led to the popularization of research-based courses, as evidenced by the President's Council of Advisors on Science and Technology explicitly recommending the replacement of traditional lab-based coursework with research courses that are discovery-based (2012).Despite the call for discovery-based research courses, not all institutions have the same access to resources to provide their students with research opportunities (President's Council of Advisors on Science and Technology, 2012).

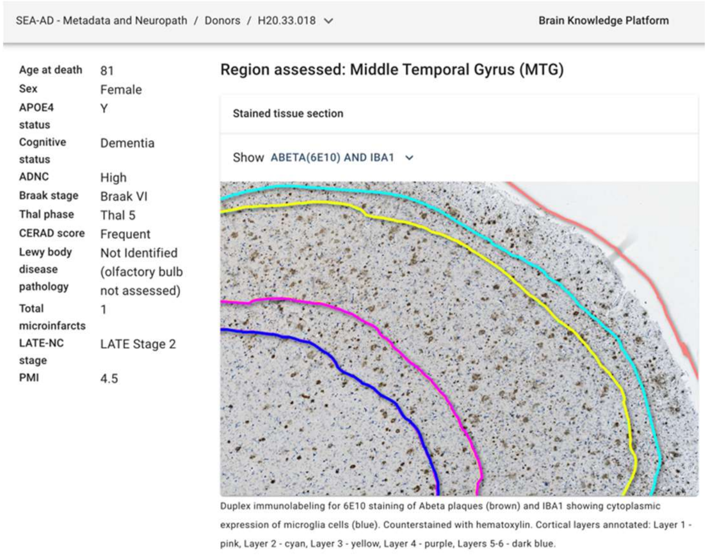
While not all institutions can provide their students with the opportunity to engage in wet-lab research due to resource constraints, open science could serve as a valuable alternative. Most open datasets only require students to have access to reliable internet and an internet-compatible device. Thus, open science can provide both resources and opportunities to those who would otherwise not have the chance to engage in research (Grahe et al., 2019). As long as students are able to access the internet, they can access a vast array of open datasets online, enabling the intellectual and creative freedom to generate their own research question, analyze the data, and come to evidence-based conclusions (Casimo, 2022). In addition to open science's ability to provide students with in-class research experience regardless of the resources available at their institution, we also believe that open science provides educators an opportunity to engage their students in socioscientific topics. In the following section, we will detail one set of open data-based lessons that were developed by the Education & Engagement team at the Allen Institute that focused on fostering students' socioscientific thinking.

Seattle Alzheimer's Disease Brain Cell Atlas (SEA-AD)

Prior to detailing the lessons, we will first provide an overview of the open data resource we used to develop them. The open data incorporated into these lesson plans serves as just one example of the vast array of open data resources that are available through the Allen Institute. The Allen Institute is a non-profit basic biomedical sciences research organization located in Seattle, WA. The Allen Institute has practiced open science since its founding in 2003 as the Allen Institute for Brain Science. While the Allen Institute originally started with a focus on basic neuroscience research, it has since expanded to include additional divisions in cell science, immunology, and a second neuroscience division, as well as basic research with clinical relevance on selected diseases. The Allen Institute also practices open science by freely sharing data, analytical tools, equipment schematics, and more. Rather than merely release raw data files for download, the Allen Institute works to create user-friendly digital tools for users, whether scientists or students, to easily navigate the data. The Education & Engagement team at the Allen Institute connects students, educators, scientists, researchers, and the general public with these open data resources, and provides materials and training to support them in using these resources. Several instructors have successfully incorporated Allen Institute data in their own classes in unique and thoughtful ways (Gaudier-Diaz et al., 2023; Ho et al., 2021; Ryan & Casimo, 2021; Juavinett, 2020).

The lessons featured in this paper use the open data from the Seattle Alzheimer's Disease Brain Cell Atlas (SEA-AD). The SEA-AD project at the Allen Institute for Brain Science and University of Washington is a collective effort to gain a deep molecular and cellular understanding of the early pathogenesis of Alzheimer's Disease (AD). The data collected within this study are derived from a full spectrum of 84 older adult donors, also referred to as "aged donors." This cohort of 84 donors includes both healthy controls and those with high AD pathology and cognitive dementia symptoms. In addition to gathering clinical and demographic information from each patient, Allen Institute scientists and their collaborators also collected brain tissue for histology and single-cell transcriptomic analysis. These data and specimens were obtained from the Adult Changes in Thought (ACT) study from Kaiser Permanente Washington Health Research Institute (KPWHRI) and from the University of Washington Alzheimer's Disease Research Center (ARDC). The ACT study from Kaiser Permanente follows initially healthy donors starting at 65 years of age through the rest of their lifespan. This type of longitudinal data allows scientists to gather crucial medical and demographic information about each donor across aging and at their time of death.

The SEA-AD data are available at [sea-ad.org](sea-ad.org) and are accessible via a web browser, with no special software required to view and analyze. The histological images are accessible via a custom neuropathology image viewer, an interface that allows students to explore images of brain tissue sections stained for key disease-associated proteins and cell types of interest. Gene expression data can be visualized through the Chan-Zuckerberg CELLxGENE tool, which allows students to explore the single-cell transcriptomic data. Students can also use the Transcriptomics Comparative Viewer or the Transcriptomics Explorer to explore gene expression relationships in cell types.



Age at death	81
Sex	Female
APOE4 status	Y
Cognitive status	Dementia
ADNC	High
Braak stage	Braak VI
Thal phase	Thal 5
CERAD score	Frequent
Lewy body disease pathology	Not Identified (olfactory bulb not assessed)
Total microinfarcts	1
LATE-NC stage	LATE Stage 2
PMI	4.5

Region assessed: Middle Temporal Gyrus (MTG)

Duplex immunolabeling for 6E10 staining of Abeta plaques (brown) and IBA1 showing cytoplasmic expression of microglia cells (blue). Counterstained with hematoxylin. Cortical layers annotated: Layer 1 - pink, Layer 2 - cyan, Layer 3 - yellow, Layer 4 - purple, Layers 5-6 - dark blue.

Figure 1. An example image from the SEA-AD dataset of an immunolabeled tissue section from a single donor with cortical layers annotated by color. Students can filter by donor, by brain region, and by which stain was applied to the tissue. In this image, Abeta plaques were stained brown and IBA1, which shows the cytoplasmic expression of microglial cells, was stained blue.

LESSON DESIGN

Since the SEA-AD dataset is open to the public and focuses on a neurological disease with considerable societal impacts, we decided that this dataset would be particularly beneficial for students. Thus, we set out to design a set of lessons that provided a scaffolded exploration of the data while also prompting students to consider the socioscientific elements of this type of neuroscience research. Given the fact that the data includes a large amount of transcriptomics, we decided to design this lesson for undergraduate biology and neuroscience students. We felt as though undergraduates who had an understanding of the central dogma and the process of transcription would be an ideal audience for these lessons. Rather than view the data strictly in terms of transcriptomics and neuropathology, we designed these lessons to ask students to critically reflect on *how* the data was collected, *who* the data came from, and *why* it is so important to consider these factors when analyzing neuroscience data. Through exploring these key questions, students are prompted to consider several socioscientific topics such as bioethics, donor demographics, underrepresented groups in research studies, and more.

How the Open Data Was Collected

Prior to asking the students to analyze the transcriptomic and neuropathological data, we first prompted students to consider how the data was collected from 84 post-mortem donors. In lesson 1, students are guided through a collection of activities and readings that ask them to explore the difference between post-mortem brain donation and living brain tissue donation. Students have the chance to [read an article](https://alleninstitute.org/news/this-is-what-its-like-to-donate-your-brain-to-science/) (https://alleninstitute.org/news/this-is-what-its-like-to-donate-your-brain-to-science/) about a living human donor, Casey Schorr, who was undergoing surgery for his severe epilepsy. As a part of the procedure, surgeons removed a small amount of healthy brain tissue in order to reach and remove the seizure focus. The article details how Schorr consented to scientists at the Allen Institute for Brain Science using the healthy brain tissue that was removed during the procedure, which otherwise would have been biological waste, for neuroscience research. After students learn about the process of living brain donation and the importance of consent from living donors, students are then prompted to consider how consent is obtained for post-mortem, or "after-death," whole brain donations. Students explore the difference between policies of expressed consent vs. presumed consent and are asked to reflect on why individuals may or may not choose to donate their brain to science depending on their personal beliefs.

This lesson has the explicit learning goal of students being able to appreciate and articulate why some people may choose to not donate their brain to science in order to underscore to students that no matter what a person cites as a reason that they would opt not to be a brain donor, their decision should be respected. Placing this discussion of human subjects open data collection at the start of the lessons was extremely intentional. We hoped that this signaled to students that it is crucial to consider how data is obtained. The lesson further contextualizes the importance of consent and bioethics in scientific research by discussing the history of science and how there are numerous examples of scientific researchers that failed to obtain consent from their participants. This discussion also provides students with a list of suggested readings that further delve into these topics and examples.

Source of Donor Data

In addition to prompting students to consider how the data was collected, these lessons also ask students to analyze the sources of donor data. Lesson 3 walks students through a guided tour of the SEA-AD donor metadata site that allows students to filter the donors based on characteristics such as gender, race/ethnicity, years of education, and more. To contextualize to students the importance of paying attention to donor demographics, the lesson asks students to read an article on the 1993 National Institutes of Health (NIH) Revitalization Act and its attempt to establish a precedent for including people who have been historically excluded from biomedical research, such as individuals who identify as women and/or people of color. Students are then asked to critically reflect on this history. For example, here are a few of the questions students are asked in lesson 3:

- *What barriers are in place that may discourage some people of color (POC) from participating in biomedical research? (Lesson 3, page 5)*
- *What solutions for improving the diversity of biomedical research cohorts can you think of that the article did not mention? (Lesson 3, page 5)*

After students are asked to reflect on the history of the lack of diversity within biomedical research, students are then prompted to explore the donor index of the SEA-AD study. Through this exploration, students will see that while the donor cohort is balanced between male and female donors, the cohort of donors is predominately white. After looking at the donor demographics of the data, students are posed the following two questions:

- *Would this cohort of 84 donors allow us to study the possible association between race/ ethnicity and AD? Why or why not? (Lesson 3, page 13)*
- *Would this cohort of 84 donors allow us to study the possible association between sex and AD? Why or why not? (Lesson 3, page 13)*

After the students reflect on the demographic characteristics of the donors, the lesson prompts students to consider how we can still use this open data while being mindful of its limitations. By coupling a discussion of donor demographics with a discussion of strengths and limitations of data, this lesson hopes to foster within the student a critical consciousness (Freire, 1970) where students can thoughtfully recognize which research questions can and cannot be addressed using this open data resource. To encourage this type of critical reflection among students, the lesson features the following passage:

“The lack of racial and ethnic diversity of the 84 donors in this study is one of its limitations. Earlier in the lesson, you read Oh et al.’s (2015) article on the lack of diversity in biomedical research studies. The field of science continues to make efforts towards addressing this demographic gap in its research to ensure that our study populations are representative of society as a whole. Conclusions from this study with regard to race and ethnicity are limited, but we can explore impacts with regard to sex and gender. While everyone is encouraged to donate their brains to science, it is imperative that people feel comfortable doing so. Improving outreach and education efforts to diverse audiences would help the field of biomedical sciences deepen its foundational knowledge of AD pathology.” (Lesson 3, page 14)

Approaching the SEA-AD data with this type of socioscientific lens is important not only because it strives towards the ideal of developing culturally relevant (Ladson-Billings, 1995; 2014) or culturally-sustaining (Paris & Alim, 2017) pedagogy, but also because these socioscientific elements of the data are imperative to fostering critical scientific thinking. Asking students to consider the strengths and limitations of data is a core principle within data analysis, and donor demographics are just as important to consider alongside sample size, data collection methods, and other important information.

RESULTS

Although we developed these lessons with the hope that they would help students use open data as a tool to foster their socioscientific thinking, we wanted to ensure that these lessons were tested with real undergraduate students prior to releasing them to the public via the Allen Institute education materials library. Our education materials library is accessible via: https://alleninstitute.org/materials-library/. In order to gain feedback from students on their perception of these open science neuroscience lessons, we hosted a one day, in-person workshop at the Allen Institute for undergraduate students. A flyer was distributed to classes at an R1 university, and students had the opportunity to volunteer to sign up for this free workshop. We recruited a total of 23 undergraduate students from this R1 university to attend the Allen Institute Neuroscience Education Workshop on October 8, 2022. Of our workshop attendees, 67% were specifically majoring in neuroscience. 62% of the students identified as women, 33% as men, and 5% as non-binary. 67% of the students identified as Asian or Indian, 29% as White, and 5% as Black or African American. Since the material encompassed 4 distinct lessons that were relatively long, we asked students to complete the first lesson on brain donation and bioethics at home prior to attending the workshop. Students worked in groups of four at the workshop to complete the lessons on their own personal electronic devices and were provided with lunch. While students were given both a pre- and post-workshop survey to fill out, few students completed the pre-workshop survey prior to arriving. Eighteen students completed the post-workshop survey and consented to their data being published. Due to the low response rate on the pre-workshop survey, this analysis will only include the data from the 18 students who completed the post-workshop survey. The post-workshop survey consisted of a series of questions that ask students their experience completing the lessons, their opinions on the lessons, and their thoughts on the role the humanities should play within neuroscience more broadly. Due to the low sample size of our student responses, we will not try to make broad generalizations with this data. Rather, we view this data as valuable anecdotal, qualitative evidence towards student perception on open data-based neuroscience lessons that embed topics of socioscientific importance.

Open Science

First, the post-workshop survey asked students a series of questions related to their experience working with open data. Since much of the literature on open science emphasizes the ability of open datasets to provide students with research-like experience, we wanted to assess how comfortable students felt working with this type of data. Students were asked to rate on a scale of 1 to 5 the degree to which they agreed with the following statements, where a 1 represented “strongly disagree” and 5 represented “strongly agree.” In response to the statement “I can analyze data collected by someone else, using their documentation to guide me,” 15 of the 18 students marked either “agree” (n = 13) or “strongly agree (n = 2). Since the idea of open science is publishing data openly for others to use and analyze, we found it extremely encouraging that students reported feeling comfortable analyzing another person’s data when given guided instructions. While a majority of students agreed with the idea that they could analyze someone else’s data when given documentation to guide them, slightly fewer students agreed with the idea that they could independently work through the experimental design process. Thirteen out of the 18 students either agreed (n = 11) or strongly agreed (n = 2) with the statement: “I can independently navigate the process of designing, conducting, analyzing, and reporting an experiment.” Notably, 4 students reported that they felt “neutral” towards this statement, and 1 student reported that they disagreed. Although this is an extremely small sample size, we feel that it is worth noting that fewer students reported feeling comfortable independently navigating the scientific process, and thus, future efforts to embed open science into classrooms could focus on providing even more scaffolding for students to follow.

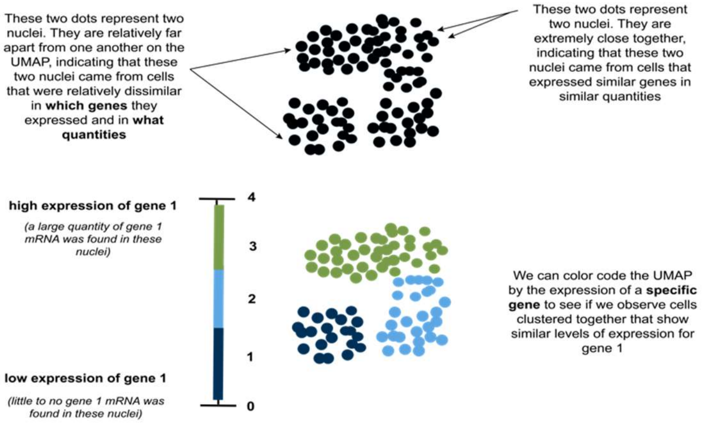


Figure 2. A graphic featured in Lesson 4 that walks students through a model of a UMAP. The top of the graphic shows a UMAP without color-coding and walks students through how to interpret the distance between two dots on a UMAP in the context of transcriptomic data. The bottom of the graphic shows how UMAPs can be color-coded to indicate relative gene expression.

Addressing the Potential of Open Data to be Intimidating

The potential for open data to intimidate students was one issue we were wary of due to a combination of factors such as the complexity of the science represented, the multiple advanced laboratory methods used, the quantitative demands of analysis, the scale of the large dataset, navigation of the software, and more. While the majority of students appeared to express agreement with the statement regarding their ability to analyze data someone else collected, students did appear to be far more apprehensive about their level of comfort in science classes as a whole. When presented with the statement, “I frequently feel intimidated in my science classes,” student responses were far more variable. 9 out of the 18 students reported that they either “agreed” (n = 5) or “strongly agreed” (n = 4) with the statement, while 3 students reported feeling neutral. Undergraduate students feeling intimidated or anxious in science classrooms is not a new phenomenon (England et al., 2019; Udo, Ramsey, & Mallow, 2004). Because the SEA-AD database contains research-grade data with complex visualization tools, we wanted to ensure that students did not feel intimidated navigating and interpreting a complex, multidimensional open dataset.

The potential for students to find this open data intimidating was a key factor we included in the design of these lessons. We suspected that students may search through the SEA-AD database and be intimidated by the transcriptomic data and the accompanying visualization tools that allow you to view gene expression data. In particular, the SEA-AD database involved in these lessons uses several Uniform Manifold Approximation and Projections (UMAPs) as a method of visualizing the transcriptomic data. UMAPs are a dimensionality reduction technique that many educators, students, and even scientists may be unfamiliar with, but which are commonly used in this area of neuroscience research. UMAPs are helpful ways to display any type of multi-dimensional data in just two or three dimensions, but interpreting them relies on an understanding of multiple background mathematical and biological processes. This can pose a challenge to students if they are not fully versed in the mathematical or biological processes underlying this visualization tool.

In order to help students interact with the open data regardless of their level of familiarity with UMAPs, these lessons provide detailed scaffolding to help students use their knowledge of transcription to interpret UMAPs. In Lesson 4, students are walked through a detailed flow diagram that outlines the steps for how a UMAP is constructed. This flow diagram leverages students' knowledge of the central dogma to explain how scientists are able to quantify the number of mRNA transcripts found for thousands of genes in thousands of cells. After walking students through how the many dimensional data is collected, students are then shown the UMAP and walked through how they can interpret what each individual dot represents. Students are also shown a direct comparison between a simplified color-coded UMAP (Figure 2) and an actual UMAP displaying some of the SEA-AD data in the Chan-Zuckerberg CELLxGENE tool (Figure 3). We hoped to provide students with a scaffolded walkthrough of how they can learn to interpret these complex dimensionality reduction visualization tools even if they have never seen them in their previous coursework.

While UMAPs, such as that depicted in Figure 3, can be incredibly intimidating as a visual tool, student feedback from the post-workshop survey supported the idea that students felt comfortable working with the data. When presented with the statement: "After these lessons, I would feel comfortable using the Allen Institute databases to explore a research question of my own," 8 of the students marked "strongly agree," 8 marked "agree," and 2 marked "neutral." We were extremely encouraged that the students reported that they would feel comfortable navigating the database on their own after completing these lessons. We also asked students their opinion on the following statement: "These lessons were a good way of learning about how to navigate complex biological datasets." 14 of the 18 students marked that they either "strongly agreed" (n = 6) or "agreed" (n = 8) with this statement, and 4 responded that they were "neutral." Although our sample size of students was small, we were highly encouraged that students reported feeling comfortable using the Allen Institute databases and that they thought that these lessons were a good way to go through the open data set. Even though open science can often involve complex data, we believe that students can be equipped to navigate these datasets when provided with the right guidance and scaffolding.

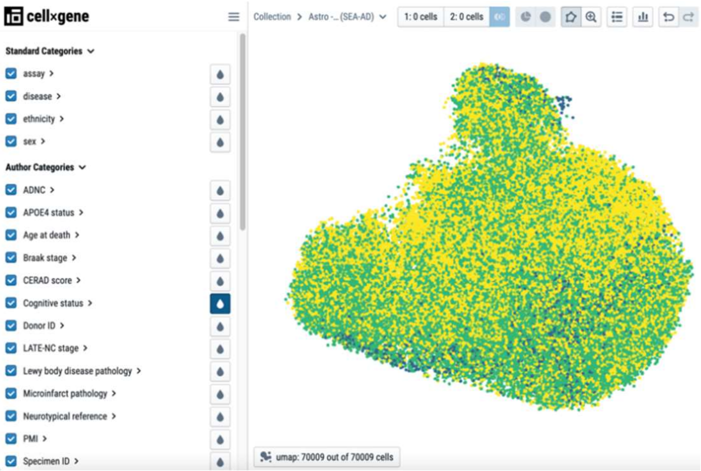


Figure 3. A screen capture from the Chan-Zuckerberg CELLxGENE tool that visualizes the SEA-AD transcriptomic data in a UMAP. This UMAP has been color-coded based on whether the cell came from a patient who had been diagnosed with dementia (yellow) or no dementia (green).

Socioscientific Thinking

In addition to gauging student perception and opinion on interacting with open data sets, we sought student feedback on the socioscientific elements of the lessons. Out of the 18 students who completed the post-workshop survey in full, 9 of them reported that they either "disagreed" (n = 8) or "strongly disagreed" (n = 8) with the statement: "these lessons were similar to assignment/lessons I have encountered in previous science courses." Because it is difficult to discern with this question if students found these lessons dissimilar to their normal science curricula due to the open data, the socioscientific content, or some other characteristic, we asked them to respond to the following statement: "These lessons had more humanities content (bioethics, sociology, etc.) than I am used to seeing in my science classes." Out of the 18 students who responded, 11 of them either stated that they agreed (n = 8) or strongly agreed (n = 3). Despite the fact that the majority of students indicated that these lessons were more humanities-intensive than their usual science coursework, 14 out of the 18 students "agreed" (n = 11) or "strongly agreed" (n = 3) that these lessons "were a good way of learning about the subject matter."

Overall, student responses to the survey provided us with valuable qualitative, anecdotal evidence that students, although not used to seeing this much humanities content embedded into their science curricula, seem to respond positively to it. We were encouraged that students felt as though these lessons were a good way of learning about the subject matter despite the fact that a majority of the students agreed that these lessons had more humanities content than they were used to seeing in their science classes. While students seemed to have an overall positive impression on the lessons and their approach to the subject matter, we were curious about the opinions of students on whether or not they believed it was necessary to embed socioscientific topics into neuroscience. Thus, we asked students to respond to the statement, "In order to understand neuroscience, you need to have an understanding of the humanities (In this case, think of the "humanities" as a category that includes subjects such as sociology, political science, and history, etc.)." Instead of responding on a 1 to 5 scale of strongly disagree to strongly agree, we left this as an open-ended question and asked students to explain their answers. Table 1 provides example responses from 8 of the students.

Students expressed a range of opinions on whether or not the humanities were necessary to understand

Do you agree or disagree with the following statement? Please explain your answer (2-3 sentences)

In order to understand neuroscience, you need to have an understanding of the humanities (In this case, think of the "humanities" as a category that includes subjects such as sociology, political science, history, etc.)

Student A	“Yes I completely agree, because it can become too easy to become unempathetic when not having sight of the bigger picture. Having some education within the humanities pushed people to consider morality and human-connectedness.”
Student B	“Yes, it is important to have an understanding of the humanities, especially when it comes to resolving equity and discrimination in science.”
Student C	“I do not think you must have an understanding of humanities to understand neuroscience. However, I think ethically you should have an understanding of society and science's impact upon it.”
Student D	“Absolutely. I feel this more strongly after reading personal stories (such as from Kasey that donated their brain while suffering from epilepsy).”
Student E	“Depends, Neuroscience deals with many of the subjective experiences in life.”
Student F	“Agree, this offers an important background. This is an essential part of supporting reasoning and motivation behind research topics.”
Student G	“I agree somewhat - parts of Neuroscience are related to humanities (such as understanding other people) but other parts are more scientific.”
Student H	“I agree as there is so much to learn about ethics within science and how we use this information.”

Table 1. Responses from students to a question asking their opinion on embedding the humanities into science coursework.

neuroscience (Table 1). Despite the fact that most students agreed with the statement, their rationale for doing so varied. Some students cited empathy and morality as important elements the humanities can contribute to neuroscience (Student A), while others cited the importance of ethics within science (Student C; Student H). While some students did not outright agree with the statement, they did concede that they saw how neuroscience can intersect with the humanities (Student E; Student C).

Overall, students appear to hold a wide range of beliefs towards the idea that topics such as sociology, political science, and history (i.e., the humanities and social sciences) are necessary in order to understand neuroscience. While students hold a variety of opinions on this type of integrated humanities/neuroscience curricula, we were ultimately encouraged by their responses to the final survey questions asking them about their opinions on the socioscientific content in these lessons specifically. When presented with the statement, “these lessons were a good way of learning about the interaction between science and society as it relates to neuroscience research and brain donation,” 15 of the 18 students “agreed” (n = 14) or “strongly agreed” (n = 1), while just 2 marked “neutral” and 1 “disagreed.”

Areas for Improvement

While students tended to respond favorably when asked about the lessons, they did provide us with valuable feedback on ways to improve the lessons in the future. A vast majority of the feedback we received on how to improve the lessons recommended that we shorten the lessons and resolve some of the technical difficulties, such as a few broken website links within the lesson PDFs. Students also reported that completing all four lessons in a single day was tiresome and that they would have preferred to have completed the lessons over a larger span of time. We were encouraged to find that these recommendations were mostly in relation to navigational challenges within the lessons rather than the content of the lessons themselves. The Education & Engagement team at the Allen Institute is working on implementing this student feedback to eliminate these navigational challenges with the lesson PDFs for future students, educators, and users.

Although these lessons were tested at a one-day workshop with a relatively small group of students, we were encouraged by the mostly positive reception of these lessons. Although we were concerned that the students may find the SEA-AD open data intimidating due to the complex visualization tools used to represent the data and the sheer amount of open data available for exploration, we were pleased that a majority of the students reported that they would feel comfortable navigating the Allen Institute database independently after completing the lessons. Students also appeared to generally agree with the idea that they feel comfortable analyzing data another person has collected, and mostly reported that they felt as though these lessons were a good way of learning about how to navigate complex biological datasets. The anecdotal evidence we gathered from our small group of students who attended our workshop provides support for the idea that with the right scaffolding, undergraduate students can navigate complex biological datasets in their classrooms. As the open science movement continues to gain momentum (Nelson, 2022), particularly in classrooms (Casimo, 2023), educators can use open data sets in several different ways. Not only can educators ask students to use open data sets to develop their own research questions and strengthen their data analysis skills, but they can also use open data as a tool by which to incorporate socioscientific topics into their classes.

DISCUSSION

Incorporating socioscientific topics into neuroscience classrooms is just one method by which educators can strive toward strengthening their students’ sociopolitical consciousness (Ladson-Billings, 1995; 2014). While the field of undergraduate biology education has identified the inclusion of socioscientific topics as a core competency (AAAS, 2009), instructors face several challenges when attempting to incorporate these topics into their classrooms. Although undergraduate biology instructors report that they see the value in incorporating these topics, instructors also report that it can often feel unnatural to embed socioscientific topics into their classes’ existing scientific content (Beatty et al., 2023). Here, we present an example of a set of lessons that uses open science as a tool for incorporating these socioscientific concepts into science curricula. Before students are asked to qualitatively analyze the transcriptomic and neuropathological data from 84 post-mortem brain donations for biological hallmarks of Alzheimer’s disease, they are first prompted to explore the donor demographics and consider critical questions of *how* the data was collected and *from whom* the data was gathered. Despite the fact that students at our workshop tended to agree that these lessons had more humanities content than their usual science lessons, they responded favorably to the statement that these lessons were, “a good way of learning about the subject matter.” Additionally, students tended to agree with the statement that the humanities are necessary in order to understand neuroscience and cited the importance of the humanities providing moral and ethical contexts to scientific research. Thus, the responses we received from our small group of students serve as anecdotal evidence that these lessons did not result in what Beatty et al. (2023) calls a disciplinary content disconnect. Students did not report feeling that the humanities content was forced to be alongside the neuroscience content on the post-workshop survey.

Overall, we were encouraged by the reception of these lessons by students and are hopeful that open science can continue to serve as a tool for incorporating socioscientific topics into neuroscience curricula. Understanding the role science plays in these real-world problems is critical, and open science datasets could serve as an invaluable tool that would allow students to directly grapple with scientific data and the socioscientific elements of that data. Whether it is donor demographics, bioethics, policies of consent in human subjects research, or otherwise, data analysis is far more than number crunching and statistical analyses. To analyze data is to critically evaluate who it came from, how it was gathered, and what it may tell us about the scientific question at hand. Open science is an untapped resource for students to engage in this type of critical analysis and begin exploring the socioscientific aspects of modern, cutting-edge biological research.

REFERENCES

Allen C, Mehler DM (2019) Open science challenges, benefits and tips in early career and beyond. PLoS biology 17(5) e3000246.

American Association for the Advancement of Science (2011) Vision and Change in Undergraduate Biology Education: A Call to Action. Washington, DC: AAAS. doi: 10.1187/cbe.10-03-0044

Bangera G, Brownell SE (2017) Course-based undergraduate research experiences can make scientific research more inclusive. CBE Life Sci Educ 13(4):573-738.

Beatty AE, Driessen EP, Clark AD, Costello RA, Ewell S, Fagbodun S, Klabacka RL, Lamb T, Mulligan K, Henning JA, Ballen CJ (2023) Biology instructors see value in discussing controversial topics but fear personal and professional consequences. CBE Life Sci Educ 22(3):ar28. https://doi.org/10.1187/cbe.22-06-0108

Casimo K (2023) Teaching and training with open science: From classroom teaching tool to professional development. Neuroscience 525:6 –12.

Casimo K (2022) Enhancing student research experiences with open data from the Allen Brain Map. J Undergrad Neurosci Educ 20(2):A178–A183.

Cooper KM, Downing VR, Brownell SE (2018) The influence of active learning practices on student anxiety in large-enrollment college science classrooms. Int. J STEM Educ 5:23. Doi: 10.1186/s40594-018-0123-6

Costello RA, Beatty AE, Dunk RD, Ewell SN, Pruett JE, Ballen CJ (2023) Re-envisioning biology curricula to include ideological awareness. Research in Sci Educ 54:13-26. Doi: 10.1007/s11165-023-10101-0

de Vries SE, Siegle JH, Koch C (2022) Sharing neurophysiology data from the Allen Brain Observatory: Lessons learned. arXiv preprint arXiv:2212.08638.

Duboue ER, Kowalko JE, Keene AC (2022) Course-based undergraduate research experiences (CURES) as a pathway to diversify science. Evolution & Development 24(5):127-130.

England BJ, Brigati JR, Schussler EE, Chen MM (2019) Student anxiety and perception of difficulty impact performance and persistence in introductory biology courses. CBE—Life Sci Educ 18(2):21. Doi: 10.1187/cbe.17-12-0284

Freire P (1970) Pedagogy of the oppressed. New York: Continuum.

Gould SJ (1981) The mismeasure of man. New York, NY: W.W. Norton & Company.

Gaudier-Diaz MM, Parekh SV, Penton RE, Roberston SD, Thomas A (2023) Sleepy mice case study: Implementation and assessment. J of Undergrad Neurosci Educ. 21(2):A108–A116. Doi: 10.5939/RHSN3470

Grahe JE, Cuccolo K, Leighton DC, Cramblet Alvarez LD (2019) Open science promotes diverse, just, and sustainable research and educational outcomes. Psychology Learning & Teaching 19(1):5–20. Doi: 10.1177/1475725719869164

Hanauer DI, Graham MJ, SEA-PHAGES, Betancur L, Bobrownicki A, Cresawn SG, Garlena RA, Jacobs-Sera D, Kaufmann N, Pope WH, Russell DA, Jacobs WR Jr, Sivanathan V, Asai DJ, Hatfull GF (2017) An inclusive research education community (iREC): Impact of the SEA-PHAGES program on research outcomes and student learning. PNAS 114(51):13531 - 13536.

Ho Y, Roeser A, Law G, Johnson BR (2021) Pandemic teaching: Using the Allen Cell Types Database for final semester projects in an undergraduate neurophysiology lab course. J Undergrad Neurosci Educ 20(1):A100-A110.

Illes J, Bird SJ (2006) Neuroethics: a modern context for ethics in neuroscience. Trends in neurosciences 29(9):511–517. Doi: 10.1016/j.tins.2006.07.002

Juavinett A (2020) Learning how to code while analyzing an open access electrophysiology dataset. J Undergrad Neurosci Educ.19(1):A94 – A104.

Ladson-Billings G (2014) Culturally relevant pedagogy 2.0: a.k.a. the remix. Harvard Educational Review 84(1):74 - 84.

Ladson-Billings G (1995) Toward a theory of culturally relevant pedagogy. American Educational Research Journal 32(3):465–491. Doi: 10.3102/00028312032003465

Levinson R, Turner S (2001) Valuable lessons engaging with the social context of science in schools. London, England: The Wellcome Trust.

National Center for Science and Engineering Statistics (NCSES) (2017) Diversity and STEM: Women, minorities, and persons with disabilities.” Alexandria, VA: National Science Foundation. Available at https://ncses.nsf.gov/pubs/nsf23315/report.

Nelson A (2022) Memorandum for the Heads of Executive Departments and Agencies: Ensuring free, immediate, and equitable access to federally funded research. Washington, DC: Executive Office of the President. Available at https://www.whitehouse.gov/wp-content/uploads/2022/08/08-2022-OSTP-Public-access-Memo.pdf.

Sam S. Oh SS, Galanter J, Thakur N, Pino-Yanes M, Barcelo NE, White MJ, deBruin DM, Greenblatt RM, Bibbins-Domingo K, Wu AHB, Borrell LN, Gunter C, Powe NR, Burchard EG (2015) Diversity in clinical and biomedical research: A promise yet to be fulfilled. PLoS Med 12(12) e1001918. doi: 10.1371/journal.pmed.1001918.

Paris D, Alim HS (2017) Culturally sustaining pedagogies. New York, NY: Teachers College Press.

President’s Council of Advisors on Science and Technology (2012) Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Online Submission, Education Resources Information Center Document ED541511. Washington, DC:

Executive Office of the President. Available at https://files.eric.ed.gov/fulltext/ED541511.pdf.

Rollins O (2021a) Towards an antiracist (neuro)science. Nat Hum Behav 5:540–541. Doi: 10.1038/s41562-021-01075-y

Rollins O (2021b) Conviction: The making and unmaking of the violent brain. Redwood City, CA: Stanford University Press.

Ryan J, Casimo K (2021) A course-based research experience using the Allen Brain Map: From research question to poster session. J Undergrad Neurosci Educ 19(2):A260 – A266.

Skorton D, Bear A (2018) The Integration of the humanities and arts with sciences, engineering, and medicine in higher education: Branches from the same tree. Washington, DC: National Academies Press.

Skorton D (2019) Branches from the same tree: The case for integration in higher education. PNAS 116(5):1865-1869.

Udo MK, Ramsey GP, Mallow JV (2004) Science anxiety and gender in students taking general education science courses. J Sci Educ and Tech 13:435-446.

Wilkinson MD et al. (2016) The FAIR Guiding Principles for scientific data management and stewardship. Scientific data 3(1):1-9.

Received October 27, 2023; revised February 2, 2024; accepted February 10, 2024.

This work was supported by the Allen Institute. The Alzheimer's Disease data from the SEA-AD project was supported by grant #U19AG060909 from the NIH; this grant was not used to support the development of this lesson. The authors thank Shannon Ramsey, Eitan Kaplan, Jeremy Miller, and the students who attended our workshop for their support and feedback during the development of these lessons. Finally, we wish to thank the Allen Institute founder, Paul G. Allen, for his vision, encouragement, and support.

Address correspondence to: Madison Meuler, Allen Institute, 615 Westlake Ave. N., Seattle, WA 98109. Email: education@alleninstitute.org

www.funjournal.org