ARTICLE
How to Integrate Neuroethics into a Neuroscience Course – And Drive Student Engagement with Core Concepts

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Students are thinking about ethical, moral, and societal implications of science—as individuals and communities—regardless of whether these topics are part of formal curricula. Ethical questions can arise from broad neuroscientific questions (What is consciousness?), emerging topics (e.g., synthetic biological intelligence), neurotechnologies (e.g., human brain organoids), and respective intersections (Could brain organoids be intelligent or conscious?). As a field of scholarship, the ethics of brain science, or 'neuroethics', can help students to situate what they are learning in the classroom within a broader socio-philosophical context that advances critical and ethical reasoning toward future neuroscience research or technologies. I will argue that neuroethics can also enhance student situational interest and cognitive engagement with core neuroscientific concepts that align with core learning objectives. Yet faculty face challenges when incorporating neuroethics topics into courses, which may include, but are not limited to i) lack of disciplinary expertise, ii) time or resource constraints within courses, or iii) the perceived lack of value in formally including ethics instructional content in courses focused on core concepts in neuroscience education. This Opinion article aims to demonstrate how these challenges can be overcome. I describe how the Value Reappraisal Model can be used as a process theory to guide integration of neuroethics into neuroscience curricula. My autoethnographic account of developing and teaching a new course provides a case study for faculty who are interested in creating curricular opportunities for students to engage with ethical issues by fostering deeper learning and appreciation of core concepts in neuroscience.

Key words: neuroethics; bioethics; core concepts; value reappraisal model, brain organoids; interdisciplinary, course design, pedagogy

Neuroscience, like most domains of scientific research, is value-laden (Doppelt, 2007; Ward, 2021) with implications for how we seek, understand, and apply scientific knowledge. Thus, ethical considerations are an integral part of doing and learning about neuroscience research, whether or not we choose to recognize those connections in the classroom. Insights from neuroethics, an active and nascent subfield of bioethics, can provide instructors with a roadmap into the ethical, moral, and civic dimensions of neuroscience. This Opinion article describes a broader vision and process for how to embed neuroethics within neuroscience education. In doing so, instructors can provide students with a pathway for thinking about and pursuing neuroscience research in ways that are responsive to inherent value-laden implications of science. By engaging with neuroethics content in the classroom, students can become better prepared to think about responsible innovation and use of emerging neurotechnologies, such as privacy concerns that arise with brain-machine interfaces. Moreover, they can learn how to design experiments and test hypotheses that reflect, accommodate, inform, or respond to diverse ethical issues–at the personal and societal level–which are likely to expand in number and relevance as our conceptual understanding of the brain, and technological ability to probe it, advance in the future. Efforts to 'mainstream' integration of ethics into neuroscience education is already underway in some countries (Walther, 2013).

But how should educators go about providing neuroethics instruction to students without detracting from core learning objectives focused on teaching neuroscience concepts? Calls to provide students, and the broader neuroscience community, with neuroethics instruction (Das et al., 2022) could be dismissed altogether, or relegated to non-science courses taught by other departments. Alternatively, faculty could take steps to integrate neuroethics into courses offered within science departments. I aim to describe how science faculty can take the latter approach by designing instructional content that incorporates ethical issues and, simultaneously, reinforces core concepts in neuroscience undergraduate education (Chen et al., 2023).

Perceptions of ethics in the science classroom can, at first glance, appear uneasy or even superfluous–after all, ethics as a discipline typically resides within humanities departments. Yet bringing ethics into the science classroom has benefits for students. It can enhance the impact of existing curricula (Yazıcı and Altıparmak, 2010), such as opportunities to apply scientific concepts to societal issues of individual interest (Keiler et al., 2017), foster more interdisciplinary thinking (Loike et al., 2013) at liberal arts institutions, promote professional identity (Liu et al., 2018), and advance inclusion and belonging among diverse students by embracing individual lived experiences and diverse value systems that enrich the communal learning environment. Neuroscience educators can make use of frameworks that already exist in the field of bioethics to provide structure and foster critical thinking around topics that may stimulate cognitive dissonance, a mental state that some scholars argue is essential for attitude change (Elliot and Devine, 1994). As a starting point, the International Brain Initiative (IBI) have identified core ethical issues and questions that should be considered in the context of advancing brain science (Rommelfanger et al., 2018). Previous work has demonstrated that engaging students on bioethics can enhance moral reasoning and judgement on neuroscientific topics (Abu-Odeh et al., 2015), and contribute toward academic achievements and positive attitudes toward science (Yazıcı and Altıparmak, 2010).

Here, I describe how embedding neuroethics within a science course can build connections between disciplines and direct student situational interest toward greater cognitive engagement with core neuroscientific concepts. Students may enter a science classroom with pre-existing misperceptions of, or lack of interest in, the subject area. By illustrating how ethics connects to core concepts, instructors can encourage engagement with instructional content that can, when appropriate, contribute to the kind of attitude change that remediates common misconceptions in science (Thomas and Kirby, 2020). To demonstrate this approach, I describe the motivation, design process, and teaching materials used to create a new course on the science and ethics of an emerging neurotechnology. I share resources that were utilized in the course and explore how these can be applied to other neuroscience courses. I believe such an approach can be widely implemented in undergraduate neuroscience programs, but only if the connection between science and ethics can be made clear and relevant to student learning.

BRINGING NEUROETHICS TO THE SCIENCE CLASSROOM

In Fall 2023, I developed a new half-semester elective for undergraduate students. This Special Opportunity in Undergraduate Learning (SOUL-23) course applied research findings from my Civic Science Fellowship at the Johns Hopkins University Berman Institute of Bioethics. The course sought to introduce students to scientific and ethical aspects of brain organoids, *in vitro* organ-like systems derived from stem cells that can be used to experimentally investigate aspects of human brain development. My research revealed that key ethical considerations of organoids–such as inferring moral status based on cognitive capacities–were highly dependent on the ability to apply core concepts in neuroscience (emergence, information processing, structure-function relationships) to human brain organoids (HBOs) as models of living brains in living humans (Boyd, 2023; Boyd and Lipshitz, 2024). Neuroscience had a critical role in informing ethical deliberation around HBOs, and more broadly, the epistemic criteria by which moral status of other beings could be assessed (Kagan et al., 2024). In turn, ethics had an essential role in clarifying which domains of cognition merited moral consideration, such as a capacity for having ‘interests’, preferences, temporal unity, and agency (Boyd and Lipshitz, 2024). The observation that neuroethics and neuroscience were interlocked, with one informing the other (Figure 1), motivated me to reassess the traditional role of ethics as merely a field that responds to scientific advances, and more as a discipline that can actively contribute to scientific discourse. Ethics can serve as a bridge between scientific and philosophical conceptualizations of cognition, wellbeing, and moral status. Making those connections more explicit in an educational context could provide a powerful, yet underutilized, strategy for recognizing the value-ladenness of science and motivate students to invest more in understanding scientific concepts of the brain.

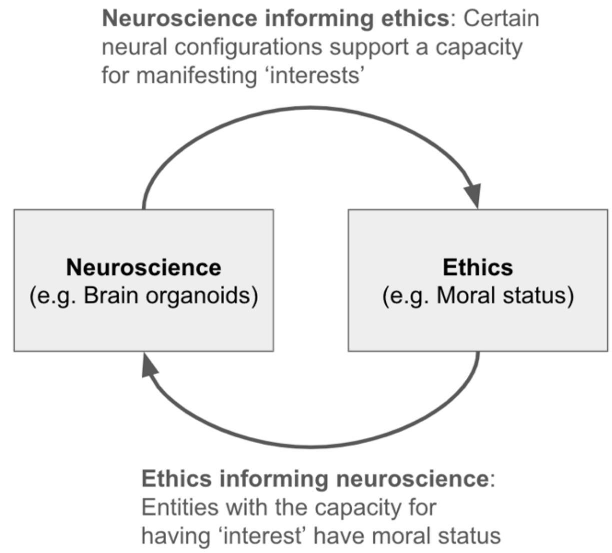

Figure 1. The conceptual interplay of neuroscience and neuroethics.

Course Structure

SOUL-23 introduced students to brain organoids as a new and often unfamiliar experimental system to study the human brain. The course was organized into four sections that explored the capacity of organoids to model the human brain at different levels of biological organization (see course overview, Table 1). In the last unit, students completed a writing assignment that applied those learnings in a peer review-styled summative assessment of an academic ethics article.

Learning objectives included students’ ability to i) compare organoids at varying levels of biological organization to the human brain, ii) apply bioethics concepts to brain organoids, and iii) model the peer review process by critically evaluating scientific and ethical aspects of the primary literature. In the first session, I introduced the philosophical concept of ‘moral status’ as a unifying conceptual theme to guide subsequent ethical-scientific discussions in the proceeding Units. Active learning has been widely used to introduce students to bioethics (examples include: Yazıcı and Altıparmak, 2010; Govindan, 2014; Abu-Odeh et al., 2015). I designed an activity to illustrate the connection between philosophical notions of moral status and the synthesis of scientific data to determine whether an entity in question demonstrates sufficient evidence for moral consideration. Students were asked to determine the moral status for a variety of organisms (e.g., bacteria, worms, flies, mice, whales, humans) and justify their choices based on self-reported criteria. Without explicit prompting by the instructor, students openly shared how their lived experiences, cultural upbringings, and individual perspectives influenced their decisions. Small group and classroom-level discussions were used to identify criteria shared across students that were necessary and/or sufficient for moral status. Common criteria included sociability, cooperation, and linguistic communication. Notably, the capacity to feel pain, enter valanced states, or suffer was not widely held among students as epistemic criteria for full moral consideration, despite these being widely adopted among professional bioethicists. These task-value activities, discussed in more detail in the following section on the Value Reappraisal Model, provided the starting point for discussing neuroscience concepts, regardless of the specific capacities deemed morally important. The activity aimed to make explicit the bridge between 'soft' concepts in philosophical bioethics and 'hard' evidence of neural mechanisms.

In subsequent sessions, students were assigned to read one primary scientific article, which focused on brain organoid biology, and a complimentary ethics article on the implications of such research (Table 1). For example, students read Kagan et al., (2022) and Milford et al., (2023) as case studies of the science and ethics, respectively, of modeling neurocognitive processes (e.g., reinforcement learning) in preparation for in-class discussions of Unit 3. The articles provided scientific and ethical perspectives on recent research that demonstrated the ability of *in vitro* neuronal cultures to 'learn' how to play the classic arcade game, *Pong*. Ethical concerns raised by these experiments— "*Do brain organoids with the capacity to 'learn' merit moral status?*" —posed epistemic questions that required knowledge of core neuroscientific concepts, including emergence, structure-function relationships, and information processing (Chen et al., 2023) in order to make normative decisions about whether such research 'ought' to continue.

In Unit 4, students applied their learnings toward writing a peer review-styled critique of an academic ethics article on brain organoids. Student were tasked with providing a scientific perspective of the article's relevance to brain organoids based on an understanding of core neuroscience concepts, and to determine whether those core concepts were adequately addressed in the article. Most of the students wrote enthusiastically regarding the need for more scientific rigor in the ethics articles and made suggestions on how such studies could be performed in the context of brain organoids. The mock peer reviews were used as summative assessments for the course. Afterwards, students were given the opportunity to publish their articles in the journal *Molecular Psychology* as Open Peer Reviews upon completing the course. Several student articles were subsequently published and are available online.

LEVERAGING THE VALUE REAPPRAISAL MODEL

Neuroethics as a field of scholarship typically has implications for policymaking, regulation, and governance. I encouraged students of SOUL-23 (and readers of this article) to reassess the value of ethics as a pathway toward enhancing neuroscience education itself. To achieve this conceptual reframing, I utilized the Value Reappraisal Model (VaRM) as a process theory to design and assess instructional content (Acee et al., 2018). Briefly, VaRM is derived from theories of persuasion and self-regulation that provide a theoretical framework for understanding the processes that shape students' subjective experience of instructional content, affective responses, attitude change, and academic achievement. As a process theory, VaRM comprises task-value interventions, described below, in the form of messages to students that 'communicate the potential value of specific academic tasks and domains … to give students various ideas about a task's relevance and make engagement in the subsequent task-value activity more fruitful' (Acee et al., 2018, p 73). Classroom activities (e.g., active learning modalities, group-based problem solving, or reading assignments) serve as mediators of attitude change and are measured through diagnostic assessments that capture the depth, valence, and relevance of students' cognitive-affective response(s) to instructional content. Thus, the goal of task-value intervention is to catalyze student's value reappraisal of why ethics is being introduced in the science classroom.

Soul-23 Task-Value Interventions

Each class session was preceded by two assigned readings that provided background for in-class discussion. Students completed 'Entry Tickets' before class to assess the impact of the assigned reading as a task-value intervention. These questions aimed to assess, using direct measures on a Likert scale, the degree of cognitive engagement, situational interest, affective response, and connection to core neuroscience concepts provoked by each assigned science and ethics article.

<u>Entry Ticket Questions:</u>

- Cognitive engagement: "How engaged were you with reading the neuroscience/ethics article?" 5-Extremely engage, 1-Not at all engaged.
- Situational interest: "The neuroscience/ethics article grabbed my attention." 5-Strongly agree, 1-Strongly disagree.
- Situational interest: "It was easy to pay attention to the neuroscience/ethics article." 5-Strongly agree, 1-Strongly disagree.
- Affective responses: "The readings made me feel uneasy/uncomfortable/bothered." 5-Strongly agree, 1-Strongly disagree.
- Core Concept: "The neuroscience/ethics article helped me understand how complex functions of the nervous system arise from simpler basic components" 5-Strongly agree, 1-Strongly disagree. (emergence, from Chen et al., 2023).

During class, the connection between the guiding ethical question(s) and core neuroscience concepts were discussed, in more detail, using data and arguments extracted from the reading. For example, evidence of consciousness is argued to be fundamental to moral status (Shepherd, 2018a), including brain organoids (Shepherd, 2018b; Birch and Browning, 2021; Niikawa et al., 2022), yet even simple two-dimensional cultures of neurons are capable of manifesting emergent functional properties of neural networks that have been ascribed as neural correlates of consciousness (Colombi et al., 2021; Habibollahi et al., 2023). Students deliberate on whether these simple systems are, in fact, conscious or revise the evidentiary basis for ascribing consciousness (Boyd and Lipshitz, 2024; Kagan et al., 2024). At the conclusion of each session, students completed an 'Exit Ticket' survey that serves to track student attitudes toward brain organoids. Tickets also enabled me to assess whether content related to neuroethics was helping to shape their understanding of neuroscience.

Exit Ticket Questions:

- "I think brain organoids could acquire some degree of cognitive capacity." 5-Strongly agree, 1-Strongly disagree.
- "There are serious ethical concerns to working with brain organoids." 5-Strongly agree, 1-Strongly disagree.
- "The bioethics issues we discussed today increased my *interest* in neuroscience." 5-Strongly agree, 1-Strongly disagree.
- "The bioethics issues we discussed today increased my *understanding* of neuroscience." 5-Strongly agree, 1-Strongly disagree.
  - "And, if so, how?" Open ended.
- "Next week, I hope we talk more about:" Open ended.

I found that students used the open-ended response questions to further probe the interface between neuroscience and ethics, which provided insight into the value reappraisal process occurring in real time. Students would inquire with questions, such as, "*How do we read the output from brain organoids and translate it into concrete actions?*", or "*Is the definition of moral status we used in class the best definition, and how can it be altered to cater toward scientific perspectives?*". I responded to these questions at the beginning of the next session and included empirical data taken from the papers or neuroscience, ethics, or social sciences literatures to demonstrate how such data was relevant (or not) to neuroethical claims/theme/ideas. Finally, I provided students with a task-value message to consider in preparation for the next session (Table 1). For example, "*Which results <from the assigned readings> are informative for making ethical decisions about organoid research?*". This task-value message prompted students to be aware of how the ethical issues presented in one article were relevant to other, and search for scientific evidence that supported or disputed the ethical concerns.

Student Responses and Feedback

The course was successful given the aims of fostering student engagement, enthusiasm, and guiding peer discussion. In addition to submitting peer review-styled summative assessment, several individuals opted to publish their final essays as Open Peer Reviews that are available online, and from which they received authorship on a DOI-assigned piece of scholarship that can be cited in future publications or resumes. The collection of diagnostic data throughout the course, as task-value activities (See Entry and Exit Tickets, examples), also provided insights into students' reactions as they were encountering instruction content. These data can provide quantitative and qualitative sources for future formal assessments of student engagement. Moreover, as the first part of every class was devoted to answering open ended questions that students submitted to the instructor, which typically focused on scientific/epistemic questions stemming from neuroethical questions, I was able to share my personal experience as a scientist-ethicist working to promote an 'experimental' view of neuroethics as an active field of research. Individual discussions with students, data collected in diagnostic assessments, and end-of-semester course evaluations indicated to me that students were engaged with the instructional content and approach taken. Student moral attitudes toward brains organoids fluctuated throughout the course, which, from my perspective, indicated that they were actively engaged with the course content. The overall enthusiasm for the instructional content was also reflected in the course evaluations, which students used to communicate the desire for more of these types of courses that could span the entire semester, cover more topics, and count toward their respective majors.

INTEGRATING NEUROETHICS INTO OTHER COURSES

Admittedly, brain organoids as surrogates for human brains provide fertile ground for discussing ethical issues (Greely, 2021) But I believe the success and lessons learned from SOUL-23 can be transferred to many, perhaps most, neuroscience courses. The emerging field of experimental neuroethics (Kagan et al., 2024) demonstrates how deeply neuroscience and neuroethics are interwoven and converge on similar sets of questions that call for interpretation of neuroscientific data, methods, and concepts.

In Table 2, I provide examples of how the lessons learned from SOUL-23 transfer to other kinds of neuroscience courses. Altogether, the examples illustrate a generalized framework of how to embed ethics in a wide variety of courses that serve undergraduate majors in biology, neuroscience, or psychology departments. As with SOUL-23, I recommend that instruction begin with a broad task-value message, statement, or question that can be deconstructed into scientific and ethical dimensions of analysis. This message serves as a common reference point for exploring cross-cutting themes over the lifespan of the course or can be tailored to individual units in a survey style course. Next, the message is situated within an established ethical framework that can be high-level, such as mainstream principles of non-maleficence, beneficence, autonomy, or justice outlined in the widely recognized Belmont Report (National Commission, 1979). Principles of non-maleficence, beneficence, and autonomy parallel concepts of wellbeing, valance, and agency that have clear connections with psychological and neuroscientific concepts. Justice brings in more social science concepts that inform access to, and benefits derived from, neuroscience research and how they are distributed across historically disadvantaged communities. For instructors with more familiarity or interest in in-depth bioethics concepts, the *Stanford Encyclopedia of Philosophy* provides an excellent resource for authoritative, yet accessible summaries of contemporary concepts in bioethics, such as moral status (Jaworska and Tannenbaum, 2023). Developing the neuroethics view within the course functions to coalesce the task-value message with bioethics concepts into a line of inquiry that directs attention back toward neuroscience. At this point, instructors may transition to more familiar scientific concepts, questions, methodologies, experimental designs, data analysis, and interpretation as the learning objectives typically associated with neuroscience courses.

Overcoming the Challenges

There are several challenges, mentioned earlier, that faculty may face when attempting to integrate neuroethics into a neuroscience course.

Challenge One

Science faculty lack relevant expertise in neuroethics. Incidentally, the rapid advance of neuroscience and neurotechnologies means that many areas of scientific research are also active areas of neuroethics research, and authoritative perspectives often originate from within neuroscience itself. Neuroscientists as practitioners offer a unique view that can enrich ongoing discourse among bioethicists. Science faculty are also likely to find neuroethics themed journals–including *AJOB Neuroscience*, *Neuroethics*, *Journal of Medical Ethics*–and science journals publishing ethics-related content, as helpful resources to learn about peer-reviewed ethical theories that are most relevant to their subject area. Moreover, within the context of teaching, instructors are not necessarily obliged to address traditional normative questions in neuroethics, such as, '*Researchers should (not) be conducting research on X based on moral argument Y".* Rather, learning activities can be seeded on ethical questions or rationale, such as defining the dimensions of moral status, which then lead to critical neuroscientific investigation: '*What kind of scientific evidence, or experimental designs, can help us better understand the neural mechanisms of agency that are claimed to be important for moral status?*' Normative approaches take the conversation away from science and toward domains of knowledge that are possibly unfamiliar to the instructor, while the approach advocated here directs the conversation back toward science. To explore ethical issues raised by a particular area of neuroscience research, instructors are encouraged to review the 'Neuroethics Questions to Guide Ethical Research' which provides a suite of example task-value messages that instructors can utilize across a range of neuroscience topic areas to prompt intersectional thinking amongst students (Rommelfanger et al., 2018).

Challenge Two

There are time or resource constraints within courses. VaRM provides a structured model for how to integrate neuroethics into existing courses. The ethics component can be effectively introduced in 10-15 minutes, including in-class discussion, and later interwoven with instructional content focused on experimental design, data analysis, and interpretation. Ethical questions help set the scene, along with any relevant historical context, and provoke situational interest among students who may otherwise be disengaged with instructional content. The need to recall science content, in relation to an ethical or moral issue, can function to maintain engagement and situational interest among students, whereby making the time/resources allocated to a particular task more impactful toward achieving learning objectives of the course.

Challenge Three

There is limited value in formally including ethics instructional content within curricula focused on teaching core concepts in neuroscience education. In my course, the value ladenness of scientific pursuits (e.g., using potentially sentient brain organoids for the benefit of advancing knowledge of the human brain) is made explicit and the subject of active discussion. These discussions began with a simple normative claim (entities with certain capacities have moral status) that provided an accessible entry point for individuals, regardless of prior neuroscientific knowledge, to share their values-aligned culturally-informed perspectives. These views laid the groundwork and motivation for exploring core concepts about the neural mechanisms of moral status-conferring capacities. Along the way, students became more aware of their own epistemic positions on moral concepts, and later connected those values with core concepts in neuroscience. Hopefully, this article has demonstrated how such an approach need not distract from students learning the fundamentals of how nervous systems develop, function, and evolve.

FUTURE WORK

My thesis–that bringing neuroethics into the neuroscience classroom can enhance student engagement with core concepts–calls for formal systematic assessment. For instance, what impact does neuroethics instructional content have on student academic achievement, interest in science as a field of study, willingness to continue in a neuroscience career path, or ability to apply such learnings in the real world? Does the structured deliberative approach I suggest promote inclusion and sharing of diverse lived experiences, or backfire with students based on demographic factors (Edwards et al., 2022)? On the instructor side, what barriers beyond those mentioned here limit more widespread adoption of neuroethics in curricula? Does the approach described in this Opinion article adequately address and overcome the challenges? Answers to these questions will help inform effective pedagogical techniques for teaching neuroethics as an integrated component of neuroscience education.

Unit	Ethics Assignment	Science Resource	Task-Value Message	Link to Core Concepts
1: Brain Organoids as Models of Human Brain Development	**Read Article:** Reardon, “Can lab-grown brains become conscious?” (Reardon, 2020)	**Watch:** TED Video: “How we're reverse engineering the human brain in the lab”	Neuroscience can raise, but also inform, ethical questions that can be investigated in the lab.	Evolution, structure-function relationships
2: Brain Organoids as Models of Human Brain Activity	**Read Article:** Birch and Browning, “Neural Organoids and the Precautionary Principle” (Birch and Browning, 2021)	**Read Article:** Trujillo et al., “Complex Oscillatory Waves Emerging from Cortical Organoids Model Early Human Brain Network Development”(Trujillo et al., 2019)	Which results from the readings, if any, are informative for making ethical or moral decisions about organoid research?	Communication modalities, plasticity, information processing, structure-function
3: Brain Organoids as Models of Human Cognition	**Read Article:** Milford et al., “Playing Brains: The Ethical Challenges Posed by Silicon Sentience and Hybrid Intelligence in DishBrain”(Milford et al., 2023)	**Read Article:** Kagan et al., “In vitro neurons learn and exhibit sentience when embodied in a simulated game-world”(Kagan et al., 2022)	Which dimensions of cognition we discussed in class matter, morally?	Emergence, communication modalities, plasticity, information processing, nervous system functions
4: Peer Review of Brain Organoid Ethics Research	**Peer Review:** Veit and Browning, “The welfare of brain organoids”,(Browning and Veit, 2023)	**Review Website:** “How to Write a Peer Review”, *PLoS*.*	Are the ethical claims supported with sufficient scientific evidence to inform normative recommendations? What kinds of scientific evidence is most relevant to the ethical principle?	N/A

Table 1. Summary of course structure and teaching resources used in SOUL-23. Each Unit included reading assignments to be completed prior to in-class discussion. Before assigning the readings to students, I provided a task-value intervention in the form of statement or question that encouraged students to think about how ethics and science provided complimentary perspectives on the same topic with the intention to connect ethics with core concepts. ‘N/A’, Not applicable. *Available at ‘plos.org/resource/how-to-write-a-peer-review’.

Course	Taks-Value Message	Ethical View	Neuroethical View	Scientific View	Link to Core Concepts
SOUL 2023: Brain organoids	Would conscious human brain organoids be a moral patient?	**Non-maleficence**: Beings with ‘interests’ have welfare subjectivity and moral status.	Brain organoids with capacities for having valanced experiences merit moral consideration.	What neural structures or mechanisms are necessary or sufficient for valanced subjectivity?	- Communication modalities - Emergence - Information processing - Nervous system functions - Plasticity - Structure-function
Example 1: Neurotechnology	Brain-computer interfaces (BCI) decode and modify cognitive functions of self-identity.	**Autonomy**: Self-determining agents (e.g., human beings) merit respect of agency.	BCIs may alter ‘self’ or compromise privacy without consent and violate autonomy.	Can BCI input change neural activity underlying psychological engrams?	- Communication modalities - Emergence - Information processing - Plasticity
Example 2: Neurobiology of disease	Cause(s) of most neuropsychiatric conditions lack reductionistic explanations.	**Justice**: Which communities or lived experiences are (de) prioritized in research?	Exclusion of lived experience in research ignores socio-cultural determinants.	How do environmental factors influence disease etiology. What counts as disease?	- Gene-environment interactions - Nervous system functions - Plasticity

Example 3: Evolutionary neurobiology	To what extent are brains resilient to rapid ecological change?	**Beneficence**: Anthropogenic factors can reduce or support wellbeing of human/nonhuman animals.	Anthropogenic factors (e.g., domoic acid) limit capacity for neural adaptation or resilience.	What mechanisms enable resilience to rapid ecological change?	- Gene-environment interactions - Evolution - Plasticity

Table 2. Description of how various courses can integrate neuroethics into neuroscience. Several examples are provided that describe connections between topics that are likely to engage diverse students on societally or ethically salient topics germane to special topics (brain organoids), neurotechnologies (e.g., BCIs), and upper-level courses (e.g., disease neurobiology, evolutionary neurobiology). Connections to community-derived core concepts in neuroscience education are provided (Chen et al., 2023). Course design conceptually flows from left to right. Abbreviations: Special opportunities in undergraduate learning (SOUL), Brain-computer interfaces (BCIs).

REFERENCES

Abu-Odeh D, Dziobek D, Jimenez NT, Barbey C, Dubinsky JM (2015) Active learning in a neuroethics course positively impacts moral judgment development in undergraduates. J Undergrad Neurosci Educ 13:A110-119

Acee TW, Weinstein CE, Hoang TV, Flaggs DA (2018) Value Reappraisal as a Conceptual Model for Task-Value Interventions. The Journal of Experimental Education 86:69–85. doi: 10.1080/00220973.2017.1381830.

Birch J, Browning H (2021) Neural Organoids and the Precautionary Principle. The American Journal of Bioethics 21:56–58. doi: 10.1080/15265161.2020.1845858.

Browning H, Veit W (2023) The welfare of brain organoids. Mol Psychol 2:4. doi: 10.12688/molpsychol.17523.1.

Boyd JL (2023) Scientific and ethical challenges of brain chimeras converge on an ‘enriched’ approach. Mol Psychol 2:16. doi: 10.12688/molpsychol.17558.1.

Boyd JL, Lipshitz N (2024) Dimensions of Consciousness and the Moral Status of Brain Organoids. Neuroethics 17:5. doi: 10.1007/s12152-023-09538-x.

Chen A, Phillips KA, Schaefer JE, Sonner PM (2023) Community-Derived Core Concepts for Neuroscience Higher Education Frantz, K, ed. LSE 22:ar18. doi: 10.1187/cbe.22-02-0018.

Colombi I, Nieus T, Massimini M, Chiappalone M (2021) Spontaneous and Perturbational Complexity in Cortical Cultures. Brain Sciences 11:1453. doi: 10.3390/brainsci11111453.

Das J, Forlini C, Porcello DM, Rommelfanger KS, Salles A, Global Neuroethics Summit Delegates (2022) Neuroscience is ready for neuroethics engagement. Front Commun 7:909964. doi: . doi: . doi: 10.3389/fcomm.2022.909964.

Doppelt G (2007) The Value Ladenness of Scientific Knowledge. In: Value-Free Science?, 1st edition. (Kincaid H, Dupré J, Wylie A, eds), pp 188–217. New York, NY: Oxford University Press..

Edwards BA, Roberts JA, Bowen C, Brownell SE, Barnes ME (2022) An exploration of how gender, political affiliation, or religious identity is associated with comfort and perceptions of controversial topics in bioethics. Advances in Physiology Education 46:268–278. doi: 10.1152/advan.00008.2022.

Elliot AJ, Devine PG (1994) On the motivational nature of cognitive dissonance: Dissonance as psychological discomfort. Journal of Personality and Social Psychology 67:382–394. doi: 10.1037/0022-3514.67.3.382.

Govindan B (2014) Moral Games Teach Bioethics at Any Level Review of: Moral Games for Teaching Bioethics Macer Darryl RJ (2008). UNESCO Chair in Bioethics, Haifa, Israel. 128 pages. J Microbiol Biol Educ 15:250–250.

Greely HT (2021) Human Brain Surrogates Research: The Onrushing Ethical Dilemma. The American Journal of Bioethics 21:34–45. doi: 10.1080/15265161.2020.1845853.

Habibollahi F, Kagan BJ, Burkitt AN, French C (2023) Critical dynamics arise during structured information presentation within embodied in vitro neuronal networks. Nat Commun 14:5287. doi: 10.1038/s41467-023-41020-3.

Jaworska A, Tannenbaum J (2023) The Grounds of Moral Status. In: The Stanford Encyclopedia of Philosophy, Spring 2023. (Zalta EN, Nodelman U, eds). Metaphysics Research Lab, Stanford University..

Kagan BJ, Kitchen AC, Tran NT, Habibollahi F, Khajehnejad M, Parker BJ, Bhat A, Rollo B, Razi A, Friston KJ (2022) In vitro neurons learn and exhibit sentience when embodied in a simulated game-world. Neuron 110:3952-3969.e8. doi: 10.1016/j.neuron.2022.09.001.

Kagan BJ, Loeffler A, Boyd JL, Savulescu J (2024) Embodied Neural Systems Can Enable Iterative Investigations of Morally Relevant States. J Neurosci 44:e0431242024. doi: 10.1523/JNEUROSCI.0431-24.2024.

Keiler KC, Jackson KL, Jaworski L, Lopatto D, Ades SE (2017) Teaching broader impacts of science with undergraduate research. PLoS Biol 15:e2001318. doi: 10.1371/journal.pbio.2001318.

Liu EY, Batten JN, Merrell SB, Shafer A (2018) The long-term impact of a comprehensive scholarly concentration program in biomedical ethics and medical humanities. BMC Med Educ 18:204. doi: 10.1186/s12909-018-1311-2.

Loike JD, Rush BS, Schweber A, Fischbach RL (2013) Lessons Learned from Undergraduate Students in Designing a Science-Based Course in Bioethics Miller KR, ed. LSE 12:701–710. doi: 10.1187/cbe.13-01-0012.

Milford SR, Shaw D, Starke G (2023) Playing Brains: The Ethical Challenges Posed by Silicon Sentience and Hybrid Intelligence in DishBrain. Sci Eng Ethics 29:38. doi: 10.1007/s11948-023-00457-x.

National Commission (1979) The Belmont Report: Ethical principles and guidelines for the protection of human subjects of research. Department of Health, Education, and Welfare: National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. Washington, DC: US Department of Health and Human Services.

Niikawa T, Hayashi Y, Shepherd J, Sawai T (2022) Human Brain Organoids and Consciousness. Neuroethics 15:5. doi: 10.1007/s12152-022-09483-1.

Reardon S (2020) Can lab-grown brains become conscious? Nature 586:658–661. doi: 10.1038/d41586-020-02986-y.

Rommelfanger KS et al. (2018) Neuroethics Questions to Guide Ethical Research in the International Brain Initiatives. Neuron 100:19–36. doi: 10.1016/j.neuron.2018.09.021.

Shepherd J (2018a) Consciousness and Moral Status. New York, NY: Routledge.

Shepherd J (2018b) Ethical (and epistemological) issues regarding consciousness in cerebral organoids. Journal of Medical Ethics 44:611–612. doi: 10.1136/medethics-2018-104778.

Thomas CL, Kirby LAJ (2020) Situational interest helps correct misconceptions: An investigation of conceptual change in university students. Instr Sci 48:223–241. doi: 10.1007/s11251-020-09509-2.

Walther G (2013) Ethics in Neuroscience Curricula: A Survey of Australia, Canada, Germany, the UK, and the US. Neuroethics

6:343–351. doi: 10.1007/s12152-012-9168-2.
Ward ZB (2021) On value-laden science. Studies in History and Philosophy of Science Part A 85:54–62. doi: 10.1016/j.shpsa.2020.09.006.
Yazıcı NN, Altıparmak M (2010) Science fiction aided biotechnology instruction: effects of bioethics group discussions on achievement and attitudes. Procedia - Social and Behavioral Sciences 2:4125–4129. doi: 10.1016/j.sbspro.2010.03.651.
Trujillo CA, Gao R, Negraes PD, Gu J, Buchanan J, Preissl S, Wang A, Wu W, Haddad GG, Chaim IA, Domissy A, Vandenberghe M, Devor A, Yeo GW, Voytek B, Muotri AR (2019) Complex Oscillatory Waves Emerging from Cortical Organoids Model Early Human Brain Network Development. Cell Stem Cell 25:558-569.e7. doi: 10.1016/j.stem.2019.08.002.

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