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Cross-Course Harmonized Assignments in Neuroscience

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https://doi.org/10.59390/BOTF3129

Neuroscience is inherently interdisciplinary. This interdisciplinarity can be lost due to the self-contained nature of each course in most undergraduate neuroscience programs, leaving students to draw these cross-course relationships on their own. We sought to address this by using short, creative research assignments on a topic of the student's choice ("Deep Dive" assignments) that provided students with the opportunity to explore common applications across two concurrently run core neuroscience courses housed in different departments. We tested whether unifying the available Deep Dive topics across the two courses improved student outcomes. Specifically, students were asked to select a topic of interest from a shortlist shared in the two courses. Our results show that harmonized, concurrent creative assignments across dissimilar neuroscience courses improved outcomes related to student interest in material, confidence in creative problem solving, content recall for the other course, and applicability to real life. To our surprise, there was no added benefit to be in the same topic for both courses. Instead, the addition of harmonized Deep Dive assignments themselves, even if assigned on different topics across the two courses, drove the outcome improvement.

Key words: undergraduate, major courses, authentic assessment, pedagogy, course design

Neuroscience is an inherently interdisciplinary endeavor. this interdisciplinarity can be lost, however due to the self-contained nature of each course and the fact that there is a considerable variety in the available courses for students in the major to choose from. Despite the core interdisciplinary nature of the discipline, students are often left to draw these cross-course relationships on their own.

"Deep Dive" assignments are short, written assignments designed to prompt students to extrapolate course content into a topic of interest (Branco, 2021). Each student selects their preferred Deep Dive topic from a shortlist that was curated by the instructor, and answers each Deep Dive prompt on the same topic. In this way, students build familiarity and expertise on a topic of their own choosing over the course of the semester. Such assignments were found to promote student interest in material and perceived course engagement (Branco, 2021).

To encourage students to make interdisciplinary connections, we introduced harmonized Deep Dive assignments with common topic options across two core neuroscience classes in the Spring of 2022. We hypothesized that these harmonized Deep Dive assignments would increase interest in the material, confidence in creative problem solving, and confidence in applying knowledge to real-world scenarios while maintaining content knowledge. Creative problem solving is a key part of undergraduate education and is critical for future innovation (National Academies, 2007; Dehaan, 2009). Students who can apply class concepts to relevant real-world scenarios have motivation and enthusiasm for the material (Blumenfeld et al., 1991).

We explored this hypothesis by collecting survey data from students in these two courses. Students were also given the opportunity to provide open-ended feedback. Students fell into one of three categories: 1) students with Deep Dive assignments on the same topic in both classes, 2) students with Deep Dive assignments on different topics in each class, and 3) students who only had Deep Dive assignments in one of the two classes. In this way we could evaluate the effectiveness of Deep Dives in an individual class versus Deep Dives harmonized across two classes. Specifically, we could answer the question: Does using Deep Dives in a harmonized way across both courses increase their benefits?

MATERIALS AND METHODS

Course Descriptions and University Context

The current paper describes the assessment tools implemented in two three-credit hour lecture courses in the spring of 2022: Molecular Neuroscience ("Molec Neuro", sophomore-level introductory course, 150 students) and Introduction to Cognitive Neuroscience ("Cog Neuro", sophomore-level introductory course, two sections consisting of 97 and 60 students). These courses were taught at University of Notre Dame, a mid-sized Midwestern private institution with a 95% graduation rate. Rachel Branco was the sole instructor of Molec Neuro, supported by six undergraduate Teaching Assistants (TA). The two concurrent sections of Cog Neuro covered the same material, but were taught by two separate instructors. A third instructor had taught Cog Neuro the previous semester. One concurrent section of Cog Neuro was supported by one graduate TA, and the other concurrent section of Cog Neuro (taught by Vanessa Chan) was additionally supported by four undergraduate TAs. See Figure 1 for schematic of courses related to this study. As these two courses are required sophomore-level classes for the Neuroscience and Behavior major (NSBH), both courses are populated by a sizeable majority of NSBH majors. The non-NSBH majors were typically either Psychology majors (for Cog Neuro) or

Biochemistry majors (for Molec Neuro). The content of Molec Neuro focuses on the basic biochemical mechanisms of neuronal transmission, including electrical properties of neurons, chemical signaling, and synaptic plasticity. The content of Cog Neuro explores cognitive functions and their neural correlates at a neural systems level, covering major topics such as attention, language, learning, and memory. There are no laboratories associated with either course. Approximately 60% of students in these classes are interested in attending medical school after graduating.

Deep Dive Assignments

Before the semester started, six undergraduate TAs for Molec Neuro selected a topic in the field of Neuroscience that was interesting to them. They were provided general themes from which to select a topic: Neurodegenerative Disorders, Psychoactive Drugs, Psychiatric Disorders, Brain Injury, Lifespan Development/Disorders, and Sociocultural Differences. From these themes, the six selected topics were Parkinson's Disease, Psychostimulants, Posttraumatic Stress Disorder, Traumatic Brain Injury, Developmental Disorders, and Cultural Norms. Students ranked the topics they were most interested in using Google Forms. Each student was sorted into a 'Topic Group' such that every student was in one of their top three choices and each Topic Group contained approximately the same number of students. This student sorting was facilitated by a simple homemade Python program that we can share upon request. Each TA became the leader of that Topic Group, providing background reading, answering topic-specific questions, and grading Deep Dives. TAs used Canvas to shepherd online discussions related to their topic. Deep Dive prompts were open-ended questions related to the class material from the preceding two weeks. These questions involved experimental design or drawing/explaining concepts. Students were expected to find research outside of class material in order to be able to answer the Deep Dive prompt. TAs were instructed to examine each Deep Dive for evidence of detail, whether the student appropriately answered the prompt, whether the student integrated class concepts, and how well the student incorporated outside information. Submissions graded the Deep Dives for either full, half, or no credit based on effort – perfection was not expected. Honest, but flawed, grappling with the prompt was sufficient for full credit. TAs provided feedback where appropriate. Consistency was ensured between TAs via weekly group meetings with the course instructor. Because they were grading based on effort and each TA was only responsible for their own Topic Group, grading was completed quickly. Supplementary Material 1 includes the Deep Dive prompts for both the Cog Neuro class and the Molec Neuro class. Supplementary Material 2 includes written instructions to students for the Deep Dive assignment, which we will use in both of our classes moving forward.

Revision of Course

One section of Cog Neuro introduced Deep Dive assignments in the Spring 2022 semester, replacing two writing assignments that were designed to compare and critique an article of choice from a limited set (Wood and Chan, 2020). Due to discrepancies in TA numbers and availability between the two courses, only five topics were made available to students of the six from Molec Neuro. Molec Neuro had used Deep Dive assignments starting in Spring 2021. In both Cog Neuro and Molec Neuro, the Deep Dive assignments were worth <30% of the final grade.

Evaluation of Success of harmonized Deep Dive Assignments

In order to evaluate the success of harmonizing topics across courses, we compared outcomes across three groups: 1) students who had the same Deep Dive Topic in both Molec Neuro and Cog Neuro ("Same topic"), 2) students who had different Deep Dive Topics in Molec Neuro versus Cog Neuro ("Dif topic"), and 3) students who only had Deep Dive assignments in Molec Neuro, but not Cog Neuro ("Limited DD") (Figure 1). We solicited feedback via a survey. The survey asked students to rate on a seven-point Likert scale their own interest in the subject matter, their

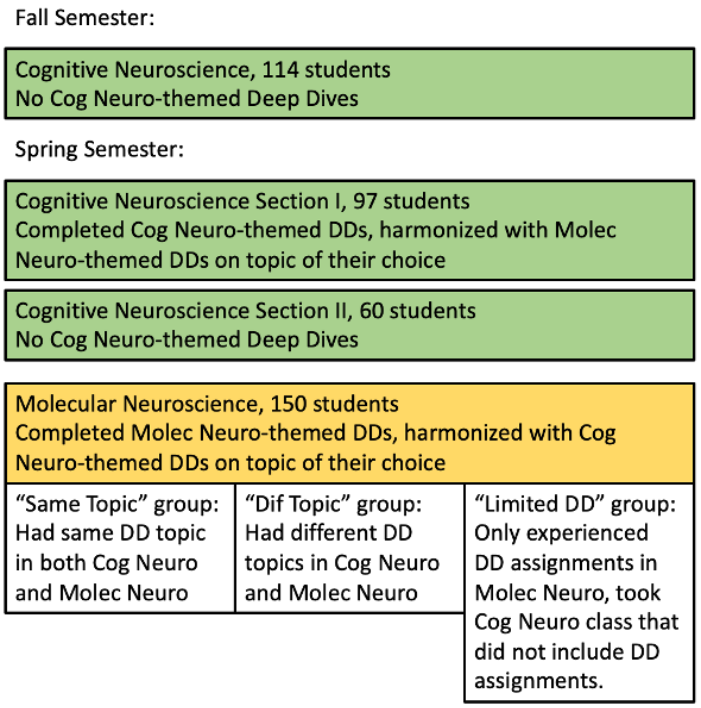

Figure 1. Schematic of experiment. Students could take one of three offerings of Cognitive Neuroscience ("Cog Neuro") during their sophomore year: one section was offered in the Fall and two sections were offered in the Spring. All three sections of Cog Neuro were taught by different instructors. Only one section of Cog Neuro offered harmonized Deep Dive (DD) assignments. There was only one offering of Molecular Neuroscience ("Molec Neuro") in the Spring. Virtually all students in the Molec Neuro class also took Cog Neuro during their sophomore year. Thus, out of the students in Molec Neuro, students fell into one of three groups. The first group, named the "Same Topic" group, had the same DD topic for both their Molec Neuro and Cog Neuro classes. The second group, named the "Dif Topic" group, had DD assignments in both Molec Neuro and Cog Neuro, but their assignments focused on different topics. The last group, the "Limited DD" group, only experienced the DD assignment in Molec Neuro, as they took one of the sections of Cog Neuro that did not include DD assignments.

confidence in creative problem solving, their self-perceived ability to recall course material, and their ability to apply class concepts to real-world scenarios, with 1 being 'less interested/confident/able' and 7 being 'more interested/confident/able'. Students could also provide open-ended feedback to the following prompt: "Use this space to let me know any other thoughts regarding the Deep Dives. If applicable, I am also interested in how you felt about doing Deep Dives in both Molec Neuro and Cog Neuro." Thus, we had both quantitative and qualitative data to assess the efficacy of our intervention.

Analysis

The quantitative data were initially analyzed in a multivariate regression analysis conducted with R (R Core Team, 2022). The main independent variable was the group in which students belonged regarding their Deep Dive exposure (same topic, dif topic, limited DD). As a secondary independent variable, we assessed the degree to which this varied between the different sections of Cog Neuro by adding a variable of Cog Neuro instructor. We applied dummy coding to each independent variable, with 'limited DD' and the class taught by Vanessa Chan as the reference groups. Subsequent univariate analyses were conducted for each dependent variable, and post-hoc comparisons were done using estimated marginal means.

The qualitative data were first separated by group, and a set of 19 codes was generated from reading the written comments. These codes were then organized into five main themes, two of which had two subthemes (see Results section for details).

RESULTS

Out of the 150 students offered the survey, 140 completed it. We removed 33 surveys from analysis either because they had not yet completed Cog Neuro or they had missing data. A further 21 students were eliminated even though they completed the survey, as they confused the "Deep Dive" assignment with another assignment in their Cog Neuro class. We did this to ensure that the remaining data reflected student opinion on the intended assignment. Thus, we analyzed 86 student surveys (30 Same Topic, 26 Dif Topic, and 30 Limited DD).

Quantitative Analysis

We first assessed the correlation of the survey responses as it related to topic interest, problem solving skills, content recall, and applicability with real-life applications with each other, using pairwise correlations. We found that each of these dependent variables was strongly correlated with the others (all Pearson coefficient values of > 0.67). Because of this, we conducted a multivariate linear regression to compare all dependent variables while accounting for their shared variance. The initial model with the effect of group as the sole independent variable found a significant effect of group (Pillai's trace = 0.350, $p < 0.001$). A model comparison that included the effect of Cog Neuro instructor did not significantly vary from a model that only had the effect of group (Pillai's trace = 0.117, $p = 0.28$), so we report the results from the model that included only the effect of group.

Across all four dependent variables, there was a significant main effect of group (all $p < 0.05$, Figure 2). Post-hoc pairwise tests revealed that although there was a significant difference between Same Topic and Limited DD, as well as between Dif Topic and Limited DD, the Same Topic and Dif Topic groups did not statistically differ from each other. This trend is consistent across all four dependent variables.

Based on these statistics, we can conclude that there is an effect of having Deep Dives on our variables of interest, but there is no effect of whether Deep Dives were done with the same topic or with a different topic on students' self-perceived outcomes on any variable. Furthermore, our analysis showed that there was no effect of Cog Neuro instructor or timing of Cog Neuro class (taken concurrently or prior to the Molec Neuro class).

Qualitative (Thematic) Analysis

We performed a thematic analysis on student survey responses describing their thoughts regarding Deep Dives. Several themes emerged from this. First, students commented on the nature of the assignment, describing the DD assignments as fun and an opportunity to be creative. They also appreciated the fact that the assignments were short and freeform, requiring students to conduct independent research in order to complete them. Some students reported this as an opportunity to improve their confidence in engaging with scientific literature:

> *I loved the deep dives, I thought they were interesting and it was a reasonable amount of work. I think it helped related course material to real life but it also made me better at reading science literature. (Same Topic)*

> *I loved the deep dives. They are one of my favorite assignments because they are a low-stakes (so low stress and enjoyable), but not low-stakes enough where I BS them. I find it really fascinating to read literature and now all my research I do (even personal) I look for scientific literature first! (Dif Topic)*

Students also identified feelings of frustration around the open-endedness of the assignment, expressing this while recognizing its merits. Some students found it hard to identify research that seemed relevant, while others would find themselves stumped by how to go about answering the prompt. As one student wrote:

> *I like the deep dives but sometimes I felt very limited with the specific topics for each one. I found the cog neuro ones harder in this aspect because I would often not find a related article and sometimes had to draw my own conclusions. While I think this aspect was good and helpful for my learning, it also bothered me that I didn't have a legitimate answer sometimes and I didn't know if I was just completely making something up. (Same Topic)*

Secondly, students consistently posited that sharing DD

assignments between classes helped make the assignments more manageable and emphasized relationships between the courses. The similar format made getting the hang of the assignments easier, and being able to apply information from one course to another:

> *I liked having the same topic in both Cog and Molec Neuro because I was able to gain a much deeper understanding of my topic. The prompts were not the same ever but sometimes complimented each other, which gave me a base to go off of. (Same Topic)*

> *… I also thought it was interesting because I had the same topic for both but I never wrote about the same thing. In this sense it opened my eyes as to how widespread research in neuroscience can be even on just one topic. (Same Topic)*

Interestingly, these comments about cross-class reinforcement appeared regardless of whether the student had the same or different DD topic between classes. The similar format appeared to be sufficient for this transfer:

> *I honestly really liked the deep dives, especially in conjunction with the cog neuro ones. I was able to pull information from one class and apply it to the other, which felt really cool. (Dif Topic)*

> *…I felt like the deep dives have helped me see how the classes can complement each other, and both let me explore further topics that interested me. (Dif Topic)*

Thirdly, students had variable feelings surrounding topic alignment between classes. Because students did not always get their first choice, or a topic was available in one class but not the other, they may not have been put in their desired group, or given two different topics even though they wanted one. There appeared to be two mediating factors for whether they appreciated or regretted being in the same topic group in both classes. The first was their own interest in their selected topic, or if they had a preference for getting a closer look at one topic versus getting a broader scope of multiple topics. Some students with the same topic in both courses thought all students should have the opportunity to do the deeper dive into one topic that they were able to do, while others wanted more variety in topic selection or subdivision in topics.

> *I enjoyed having the same deep dive topic for both Molecular and Cog neuroscience because I was able to gain a deeper understanding of the topic and connect the two classes in a stronger way. (Same Topic)*

> *I think having different topics in each class was nice because I was able to research different things. (Dif Topic)*

The other reason for variability of feelings in topic alignment appeared to do with the perceived disparity in workload or difficulty. There were students in both the same topic and different topic groups that felt there was a difference in how much work they had to put in, even if they sometimes came to differing conclusions regarding what to do about it:

> *I would definitely recommend doing the Deep Dives in the future. I feel that it greatly benefitted me to have the same topic for both classes, however, so [sic] I feel that people with two different topics had to work harder than I did. I would recommend somehow lining it up so students do the same topic for both if possible. (Same Topic)*

> *… I do like having two different deep dive groups because it makes you explore more topics and I think in the future people should be required to do two different ones because I've heard of people just writing very similar responses for both. (Dif Topic)*

Fourth, students commented that the DD assignments allowed them to apply class knowledge in a novel fashion, reinforce their content knowledge, and generally fulfilled the objectives that we set out to achieve with the assignment. Some students even reported this being a method of studying for them. These comments generally were in alignment with the quantitative results reported above: not everyone felt this way, but the majority of commenters spoke positively of the assignment helping them foster interest and understand the applicability of course content.

> *I really enjoyed the deep dives in both courses! It was really interesting to connect the topics to real life issues and being able to use concepts in class in bigger ways was very beneficial to my learning and sparking my interest in the topics. (Same Topic)*

> *I never did deep dives in cog neuro, but I really liked the idea of them and how we got to apply what we have learned in class to a real world issue. It made me more interested in the material we were learning. (Lim DD)*

Lastly, students commented on ways to improve the implementation of the DD assignments. Specifically, students felt that the two classes should ensure that the DD instructions were identical in both classes and that due dates for the DD assignments should be coordinated. Slight differences in the way DDs were supposed to be written meant that some students found themselves juggling different sets of instructions. Students with different topics in both classes also reported being confused occasionally regarding which topic they had selected for which class. Regarding due dates, there were conflicting reports: although some students preferred having due dates that were the same between both courses, other students liked the fact that the due dates were not always identical so that the workload felt more manageable. In general, implementation comments came more often from students who were balancing two different topics. There was also a common difficulty identified for students who had selected one particular topic (Cultural Norms): not only were the assigned TAs in both courses interpreting the topic

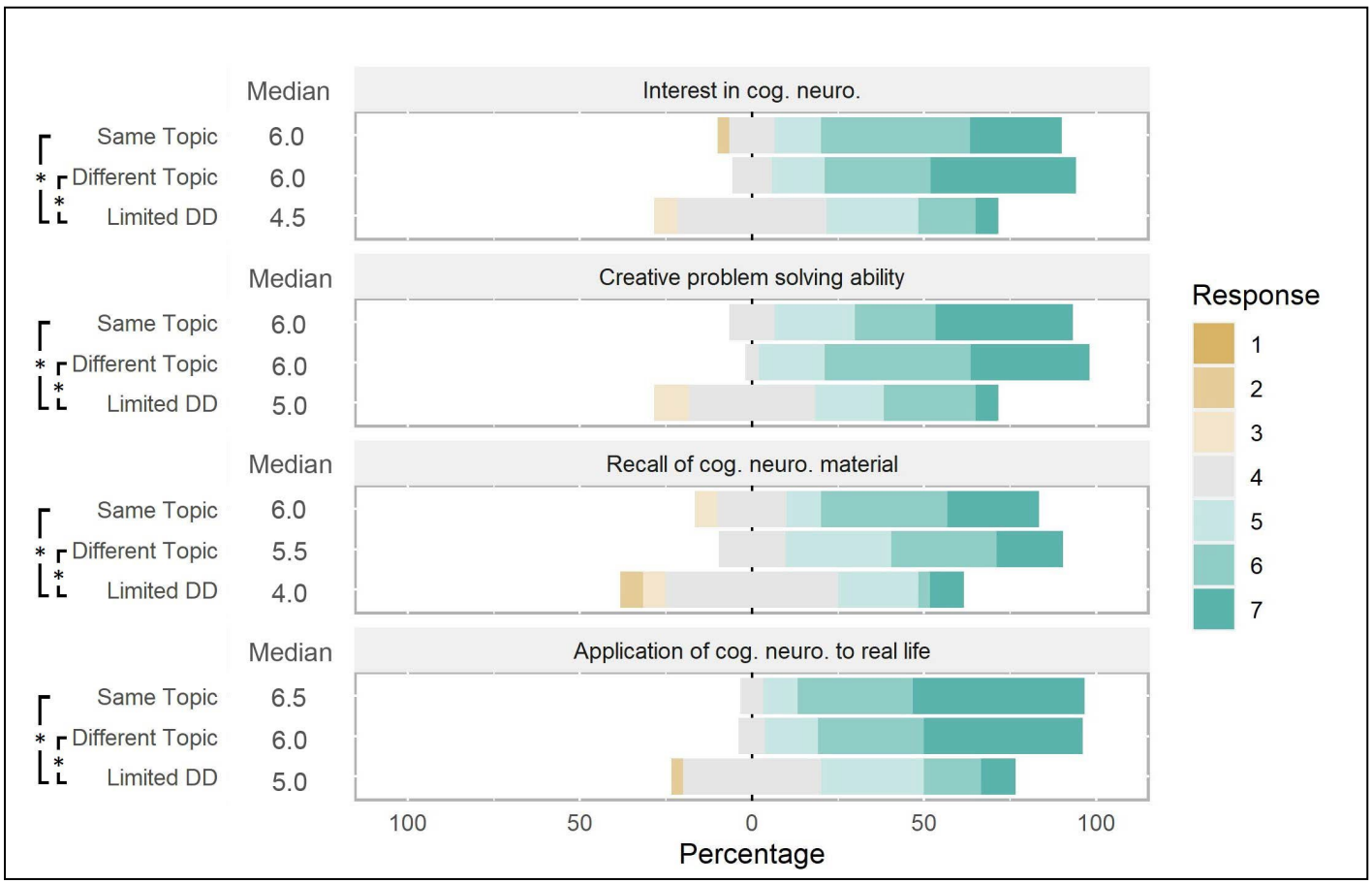

Figure 2. Results of quantitative analysis. * $p < 0.05$

differently, students found it harder to complete:

> *I know that it would be difficult, but I wish that the cog neuro and molecular deep dive topics were more different because I picked cultural norms for both of them because that was the most interesting topic to me, and I wasn't super invested in any of the other topics. (Same Topic)*

> *I wish the deep dive questions were more applicable to different topics. To specify, I was in the culture topic and I felt like it was really hard to find relations to the questions. I felt like every deep dive I was making a slight stretch and not really getting to know my topic. (Lim DD)*

DISCUSSION

Our results show that harmonized creative assignments improve student outcomes related to student interest in material, confidence in creative problem solving, and applicability to real life. We also assessed whether there was any benefit to the students partaking in the same topic for these creative assignments in both classes relative to different topics for the two classes. To our surprise, there was no added benefit to be in the same topic for both courses. Instead, the addition of harmonized Deep Dive assignments themselves, even if assigned on different topics across the two courses, drove the outcome improvement.

It may be that the Deep Dive assignment itself encouraged students to think about topics in neuroscience in a deeper way, and thus the actual topic was less important than the process of practicing research and communication. Indeed, with each Deep Dive assignment, the student was expected to perform independent research, extract succinct information from complex sources, independently synthesize these ideas, and effectively communicate their findings. One could imagine that the mere practice of this process, regardless of topic, is itself helpful in the outcomes that we measured. In retrospect, we never assessed the student perception of Deep Dive difficulty, or how it changed their perspective on the scope of neuroscience itself. These questions would give us further insight into whether student attitude around neuroscience and the process of critical thinking as a whole was changing by completing these assignments.

Strengths of this Approach

There are a number of advantages to using harmonized Deep Dives in multiple courses. First, as shown by the data in this paper, this approach yields effective results to student outcomes. Second, it is an easy way to explicitly highlight a central tenet of neuroscience – that the field is interconnected across multiple disciplines, and that this interconnectedness is useful for real-life applications. Third,

the investment on the part of the instructors is minimal. It is necessary to coordinate the short list of potential topics, to coordinate assignment timing and grading expectations, and to make sure that each class has the grading capacity to support these assignments. Once these parameters are set, however, at the beginning of the semester, there is no need for further work or coordination above and beyond administering the Deep Dive assignments. Fourth, by using Deep Dive assignments in multiple classes, the students gain experience in reading/interpreting/communicating about neuroscience research in multiple fields. One can imagine incorporating such assignments in even more classes, which would provide students with more opportunity to learn about research in more disciplines.

Ideas for Improvement

In our implementation of the harmonized Deep Dive assignments, we never explicitly laid out the rationale behind the setup to our students. For the Spring 2022 semester, we avoided this rationale so that we could gather data about student experiences without coloring them with our expectations of what their experiences would be like. In the future, making objectives and task steps more transparent would more effectively orient the students to the goals of these harmonized assignments. In general, transparency in assignment guidelines has been found to improve students' academic confidence (Winkelmes et al., 2016); it may be all the more important for our students to be told our implicit but desired outcome of interdisciplinary awareness. Although there were students who reported experiencing transfer between courses irrespective of topic alignment, it remains unclear whether this particular outcome is better achieved by assigning the same topic in both classes. Future research into this question specifically would help with determining whether having the same or different topics overall is more beneficial, or if there is a trade-off between cross-course connections and individual student motivations. For students who are only taking one class or the other, it would be helpful to still give the objectives for why we assign Deep Dives, and explain that they will still get the benefits of increased application/interest/problem solving skills. Practically, we could improve our implementation by being more thoughtful about assignment due dates and specific language of the instructions given to the students, as well as being more intentional about the selection and feasibility of topics.

Overall, we observed improvements in student outcomes related to student interest in the material, student self perceived ability to creatively solve problems, student perception of applicability to real world applications, and perceived content recall of the opposing course due to using Deep Dive assignments concurrently in two disparate neuroscience courses. The implementation of these assignments was relatively easy on the part of the instructors. In the many Neuroscience undergraduate programs that draw from multiple disciplines, we recommend consideration of such harmonized, creative assignments.

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Received October 26, 2022; revised January 11, 2023; accepted February 9, 2023.

The authors thank Mr. Perry Harlan Cliburn and Dr. G. Alex Ambrose for their valuable input on this study.

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