ARTICLE
Structured Worksheets: Simple Active Learning Strategies to Increase Transparency and Promote Communication

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There are varied pedagogical approaches that promote active learning in the classroom, many of which have been shown to have positive impacts on student outcomes. Simple active learning techniques that do not require costly resources or extensive time investment for faculty may increase the likelihood of instructor adoption and decrease student anxiety or skepticism about such approaches. In two upper-level Neuroscience electives, scaffolded worksheets were utilized to increase transparency in instructor expectations and subsequent assessment, and to support student contributions to learning and group work. Scaffolded worksheets that presented practice questions were provided in a Behavioral Neuroscience course; students completed the worksheets alone or in teams, and course time was used for review and additional clarification. Shared group worksheets were used to support a group project in a mid-level Cognition course. These worksheets delineated expectations for the assignment and gave a timeline for in-class and out-of-class meetings with required individual, graded contributions to support group progress. Worksheets also enabled instructor feedback throughout the project. When surveyed, students responded positively to the worksheets for their ability to support learning and alleviate some of the common concerns associated with group work. This approach was also easily expanded during the pandemic to provide more time for active learning, and to maintain communication and ensure support of student learning during periods of remote learning due to Covid-19. Active learning techniques, particularly those that promote transparency and metacognition, are likely to benefit students and create a more inclusive classroom. Yet care must be used in the implementation of these approaches. In addition, barriers exist to the utilization of active learning, including a lack of support for such work at the institutional level. Greater institutional investment in these approaches will likely broaden their use and extend their impact.

Key words: active learning, metacognition, worksheets, group work, teamwork, assessment, inclusivity

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Active learning is generally characterized by pedagogy that engages students in the construction of their own knowledge (Carr et al., 2015). This approach has gained considerable attention as an effective means to promote student learning beyond traditional lecture (Prince, 2004; Michael, 2006). The student benefits of active learning include improved conceptual understanding of material (Freeman et al., 2014), increased self-efficacy (Ballen et al., 2017), motivation (Cicuto and Torres, 2016), cognitive skill development (Freeman et al., 2014), and persistence of students in their courses, majors, and STEM fields (Haak and Freeman 2011; Graham et al., 2013). There are varied ways to implement active learning; student research, problem-solving in groups or teams, in-class worksheets, small group work or group projects, and others have been classified under this umbrella (Michael, 2006; McConnell et al., 2017). No single approach has been definitively identified as the most beneficial strategy when engaging in active learning techniques, though some are exploring this question (Weir et al., 2019)

Some active learning methods involve substantial redesign of the course (McConnell et al., 2017; Theobald et al., 2020) or extensive use of technology or other resources. Faculty and students may resist such approaches due to a lack of time, familiarity, or available resources to effectively navigate such changes (Knight and Wood, 2005). The use of guided worksheets, an established active learning approach (Narjaikaew et al., 2009; Sujarittham et al., 2016) may be a mechanism through which instructors can engage students in active learning that is low-cost, versatile, and easy to use. Guided worksheets also do not rely on knowledge or access to technology (Sujarittham et al., 2016; Weir et al., 2019), and may be used in classrooms of varied size (Leslie-Pelecky, 2000). As worksheets are commonly used in several settings, they may also be more familiar and less intimidating to students (Cleveland et al., 2017). Depending on the design, worksheets can be also used to help students engage in self-assessment (Narjaikaew et al., 2009). While worksheets can be used as part of a more extensive course redesign such as process-oriented guided inquiry learning (Daubenmire et al., 2015), other approaches use worksheets as a simple supplement to lecture, videos, class discussions, and other pedagogies (Narjaikaew et al., 2009; Sujarittham et al., 2016). Students report that worksheets are helpful, and worksheets have been shown to promote learning gains (Narjaikaew et al., 2009) and help students understand and think about content more thoroughly (Georgiou and Sharma, 2015). While all active learning strategies appear to benefit student learning, recent work suggests that in certain contexts, worksheets may produce particular gains including increased conceptual understanding, and improved student ability to make real-world connections with content (Cleveland et al., 2017; Weir et al., 2019). Worksheets that provide practice questions that model exam questions can improve transparency of faculty expectations as well.

Group work is another common active learning approach (Phipps et al., 2001; Fink, 2002). Small group work has been shown to enhance learning through active student involvement (Chiriac, 2014). Group work can also serve as an incentive for learning and provide an opportunity for students to apply learned knowledge and skills (Chiriac, 2014). While students generally have positive impressions of group work (Phipps et al., 2001); they do express concern regarding the coordination of schedules (Gotschall and Garcia-Bayonas, 2008) and equitable work distribution (Hagen, 1996; Gotschall and Garcia-Bayonas, 2008), and may react negatively to common group grades (Phipps et al., 2001), particularly given the risk of differential effort. Yet research suggests that instructor strategies to monitor group work, a fair assessment system that differentiates performance based on student effort, inclusion of some in-class meeting opportunities, and specific criteria for assessment and individual contribution may alleviate some student concerns and promote a positive experience for students (Pfaff and Huddleston, 2003).

Active learning is also called “student-centered learning.” Inherent in this definition is the idea that students are active participants in the learning process; this can be maximized if students understand course and assignment expectations clearly and are also engaged in course assessment (Balloo et al., 2018). Student-centered assessment allows students to evaluate their own learning and progress (Tan, 2008), an important part of metacognition. Metacognition has generally been defined as “thinking about one’s thinking,” but in the educational context, metacognition often refers to student awareness of learning process, learning progress, and how one should adjust their preparation or studying to maximize their own learning (Tanner, 2012). Various metacognitive practices have been shown to promote expert-like thinking (Otero and Gray, 2008) and gains in self-efficacy (Clauss and Geedey, 2010). Worksheets as active learning tools may promote metacognitive strategies and lead to a shift towards more expert-like attitudes as well (Cleveland et al., 2017). Combining worksheet completion with explicit self-assessment may maximize the benefit of each approach. Subsequent instructor evaluation of understanding in an in-class group setting can allow faculty to address challenging subjects with further clarification and/or additional problems, consistent with just-in-time teaching techniques (Novak, 2011, Sujarittham et al., 2016).

Some student concerns regarding group work could also be alleviated by the use of shared worksheets that guide the process of group work over the course of the project. These worksheets can be used to set expectations for individual group member contribution, outline a timeline with requirements for out of class work, enable student-faculty interaction offline, and provide a mechanism for differential grading based on student effort. Specific grading criteria and consequences for a lack of individual contribution can also be clearly stated, and faculty can monitor student effort and progress and share feedback within the shared document itself, or through faculty-group meetings as needed.

Based on the described benefits of these varied approaches, two versions of scaffolded worksheets were used as active learning strategies in two separate courses. Scaffolded worksheets that were completed in an upper-level Behavioral Neuroscience course provided students with specific examples of the sorts of questions that would be included on exams and enabled practice completing such problems. These questions were labeled based on “Bloom’s taxonomy” (Crowe et al., 2008) to try to increase student awareness of the degree to which they fully understood the material and questions that were more/less difficult, in the hopes of prompting exam preparation that went beyond rote memorization. These worksheets were completed alone or in pairs during class time to provide time for open discussion of response accuracy, misunderstandings, further explanation, and/or additional examples by the instructor. These techniques aimed to promote metacognitive monitoring, or the degree to which students could effectively evaluate their understanding of course material and ability to answer related questions (Medina et al., 2017). A second set of shared, scaffolded worksheets that supported work on group projects were used in a mid-level Cognition course. These shared group worksheets were used to outline project expectations, provide a completion timeline, and document appropriate individual student contribution to the group. Students completed graded individual assignments that supported group progress within the shared document, and the group confirmed group meetings, project progress, and questions for the professor regarding the assignment directly in the shared worksheet. The instructor used this document to differentially assign points for the work based on completion of individual tasks as well as overall project quality and the rubric for the shared group grade.

MATERIALS AND METHODS

In-Class Scaffolded Worksheets

Worksheets were created by the instructor and provided in either electronic or paper format to students taking an upper-level Behavioral Neuroscience course (Example in Appendix 1). These assessments were given to two different sections of this course: one taught Spring of 2019 (n=23 students), a second taught Spring of 2020 (n=16 students). It should be noted that the Spring 2019 section was given 6 of these worksheets; the Spring of 2020 section was given 9. In Spring 2020, these worksheets were used slightly more often after the COVID disruption during virtual sessions. The data were analyzed separately, but no significant differences were noted between sections, so they are displayed together here. The majority of the students in the course were sophomore and junior Neuroscience majors who had taken both Introduction to Psychology and Introductory Organismal Biology, as well as Research

Methods and Design. Some junior and senior Biology and Psychology students also took the course as a major elective.

During the overall introduction to the course, the instructor explained that exams would consist of varied questions. Some questions would evaluate memorization and knowledge of the presented concepts, but others would examine student ability to apply those concepts in new ways, to understand and analyze described scenarios using those concepts, or to create new scenarios using that understanding. To reinforce this idea, worksheets were provided that had similar (but not identical) questions to those that would make up exams. These questions were organized in order of “increasing Bloom’s level” and labeled with approximations of “type” - i.e., questions that were simple recall of concepts were described as “knowledge-based” questions; questions that required application and/or analysis or evaluation were labeled as such. The worksheets were presented as a means to practice and evaluate students’ own learning, direct their continued study to better support learning, and identify areas where they needed additional support from the instructor.

Worksheets were graded for completion, not accuracy, and correct answers were solicited from students and/or provided by the instructor in class to allow for clarification and further material review. Additional worksheets were provided for independent student use for further exam preparation; worksheet answers were given as separate documents to urge students to evaluate their knowledge without the answers to simulate exam scenarios. Students were also encouraged to continually self-assess the effectiveness of their preparation, understanding, studying, and progress, and to seek clarification from the instructor as needed. Similar approaches have also been used by the instructor in Introductory Psychology courses.

Example recall question:

Draw a synapse in the mesolimbic pathway. Include receptors and transporters. Show how cocaine affects neurotransmission through actions at the synapse.

Example “evaluate” question:

Chantix is a common treatment for nicotine dependence. It is a partial nicotine receptor agonist. Use your understanding of partial agonists and how nicotine affects dopamine in the synapse to discuss the use of Chantix during a quit attempt. Talk about withdrawal symptoms AND dopamine levels in your response.

Shared Worksheets for Group Project Guidance and Oversight

Online group worksheets were created by the instructor and then shared during the introduction to a group project assignment in a mid-level Cognition course class session (Example in Appendix 2). Students were granted permission to edit the worksheets during initial creation. It should be noted that concerns have been raised regarding accessibility and privacy associated with the use of shared

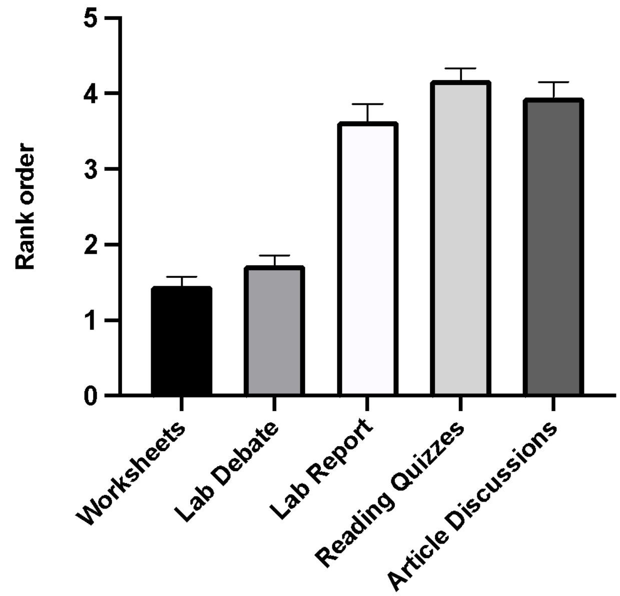

Figure 1. Student ranking of assignments in a Behavioral Neuroscience course; 1 = most beneficial to learning, 5 = least beneficial to learning. Average ± SEM is shown, n=39 students.

google docs. Google docs were chosen after determining all students already had google accounts and were often using other shared google resources. Students in the course consisted of mostly sophomore and junior Neuroscience or Psychology majors; some senior majors were also in the course. All students had taken Introduction to Psychology, and many had taken Research Methods and Design. Worksheets were used in two sections of the course taught in the spring of 2018 (n=16 students) and the spring of 2019 (n=21 students). Data analysis for each section revealed similar patterns of responses; accordingly, data are shown as collapsed across both sections.

The first section of each worksheet included the overall goals of the assignment followed by more detailed instructions, the submission due date, and a description of how the shared document was to be used, for example, “This shared document should be used to record ALL actions associated with the completion of this assignment. You will see delineated below a series of prescribed steps through which individual members are asked to complete tasks prior to assigned due dates for allotted points. Date, time, and duration of meetings should be included along with notes on what transpired during meetings. Future meeting dates must be agreed upon by all members. Meeting absences should be explained, along with details on how the absent member will compensate for their absence.

The shared document was then used to delineate out, by date, goals for each group meeting, work to be completed by individuals between meetings with available points to be earned and due dates, and questions or guidelines for group decision making and assignment of workload. The following example provides part of such a worksheet used in association with a group project assignment in the Cognition course; this approach has also been used for team research projects in a Behavioral Neuroscience course as well.

Assignment
We spent this semester developing our ability to read and understand how experiments are conducted in the cognitive sciences by reading the text, reading several articles, and reviewing multiple examples in class. You will now get to demonstrate your understanding of this process by designing a novel experiment that tests a previously unstudied question about cognition. You will do this in teams and present the information to the class. You must present adequate background and demonstrate novelty, choose appropriate methods, describe your analysis, present hypothetical results, and interpret how those results compare to published work and contribute to our understanding of the broader topic in cognition. Presentations should be 16-18 minutes long, and your required presentation file should be uploaded to D2L by 12pm on Monday, May 6.

Worksheet Prompts
Examples are provided for an in-class meeting and an outside of class meeting; more detail can be found in Appendix 2.

Meeting 1 (Held in Class)
Make sure all team members can access and edit your shared group google worksheet.

1. Read over the entire assignment information sheet. Ask any questions you have about the assignment.
2. Decide which topic in Cognition you would like to pursue for your group presentation. List 3 possibilities, discuss and then vote, and list your final decision in the google doc with notes on how you came to this decision.
3. You must hold one meeting outside of class prior to our next in-class meeting on (insert date). Agree on a date/time for this meeting, confirm all can attend, and list the date/time in the shared doc. If someone cannot attend, confirm how they will contribute.

Meeting 2 (Outside of Class Time)
Confirm attendance of all members in the shared doc.
1. You must now identify a more specific, novel area of research within the scope of your broad topic. The best way to do this is to research and read LOTS of articles. During this meeting, each student should find two articles that are relevant. Each student should post the article link, title, authors, and a 3-4 sentence summary of the article. (20 pts for EACH student).
2. Discuss the articles, and based on your discussion, confirm three potential ideas that appear novel. List them. Before the next in-class meeting on (insert date here), each student should list one idea for a specific, operationally defined independent variable related to the novel research area, and one idea for a related, operationally defined dependent variable. List them in the doc (10 pts for EACH student).

Evaluation of Worksheets
Research on survey student reaction to the use of worksheets in each course was approved by the college institutional review board. Anonymous surveys were distributed to students in each course via a link to a google form. Questions asked students to rank how scaffolded worksheets were beneficial to learning or enjoyable in comparison to other assignments, or how shared group worksheets clarified group work expectations and structure.

RESULTS
Students reported positive reactions to both types of worksheets in surveys at the midpoint or end of the course. In-class practice worksheets in the Behavioral Neuroscience course were ranked as the assignment most beneficial to learning by the majority of students (Figure 1); students who did not rank them first most often ranked them second. The other assignments for ranking were a lab debate, lab reports, reading quizzes, and research article discussions.

In-class worksheets were also ranked as the second most enjoyable class assignment (Figure 2). Students commented that, “(the worksheet) really helped me prepare for exams,” and “gave us a chance to discuss concepts that weren’t clear in class,” or “helped give me an idea of what to expect on the exams, which made them much less stressful.”

Guided group worksheets used to support a group project in a Cognition course were ranked positively for their ability to clarify instructor expectations (Figure 3). Students also ranked the ability of worksheets to help the group structure their work positively. Student comments included mostly positive remarks such as, “we all did work between meetings,” and “the worksheets made us all participate.” There were a few negative comments such as, “even with the worksheet, some people didn’t do their job,” and “one group member never posted their work but expected us to catch them up,” which suggests even written expectations may not alleviate the tendency for some students to fail to contribute to the project.

DISCUSSION
Worksheets were effective in supporting transparency, communication, and active learning in their respective courses. Students regarded in-class worksheets as the most valuable assignment to support learning in an upper-level Behavioral Neuroscience course; they were also ranked as enjoyable by students. Students actually requested additional worksheets to support their learning and review; these worksheets with/without answers were provided as study aids. Students performing work in groups reported that worksheets improved clarity on grading, expectations, and timelines for group work and also improved the structure of group work. These improvements address some of the most common concerns students have about group work (Pfaff and Huddleston, 2003; Gotschall and Garcia-Bayonas, 2008).

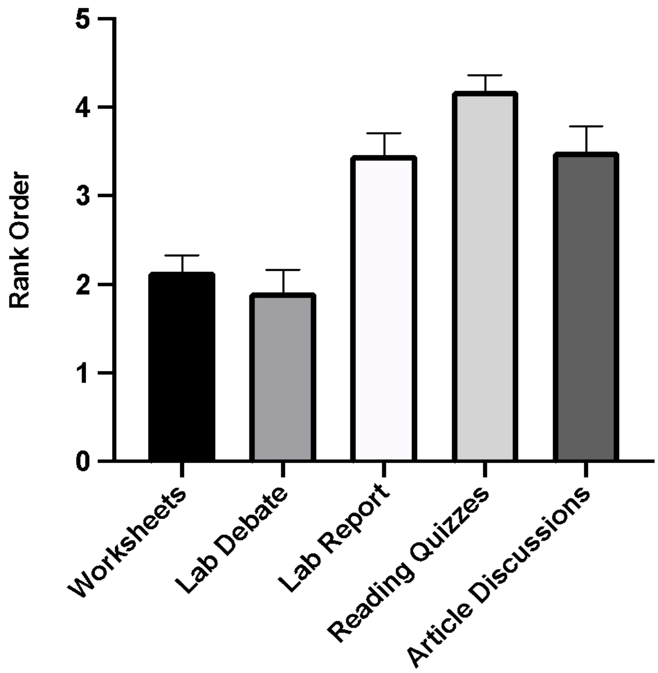

Figure 2. Student ranking of assignments in a Behavioral Neuroscience course, 1 = most enjoyable, 5 = least enjoyable. Average ± SEM is shown, n=37 students.

Challenges and Limitations of Described Strategies
While students in the current study reported positive reactions to both types of worksheets, improvements in learning and/or performance were not evaluated. Previous studies also report that students react positively to worksheets (Podolak and Danforth, 2013), prefer them to some other course components (Podolak and Danforth,2013), and find them helpful (Narjaikaew et al., 2009; Georgiou and Sharma, 2015; Sujarittham et al., 2016). There are studies that document learning gains (Sujarittham et al., 2016; Cleveland et al., 2017; Weir et al., 2019), but some reports suggest the specific content and structure of the worksheets may be important to consider in future research (Narjaikaew et al., 2009; Sujarittham et al., 2016). In addition to the response to survey questions, when asked what would be useful to further support their learning and performance in the course, more than half of all students asked for additional worksheets and/or sample questions to aid with studying, with time to review and discuss the answers. Future work could evaluate whether or not the use of worksheets improves learning; overall course grades, exam performance, or specific performance on exam questions that were emphasized on worksheets (vs. those that were not) could all be measures that might indicate an impact on learning.

While worksheets also appeared beneficial to the structure and experience of group work, there are factors outside those acknowledged and addressed here that can impact group or teamwork effectiveness in the classroom. Group construction, who decides group membership, student identity including membership in traditionally underrepresented groups, differences in student goals and motivation, interpersonal and group work skills can all impact the success of group work in the classroom (Phipps et al., 2001; Gotschall and Garcia, 2008; Chiriac, 2014; Hodges, 2018). In the current approach, students were allowed to select into groups in most instances; the instructor ensured inclusion of all students in groups prior to initiation of any work. While students do express concerns (Pfaff and Huddleston, 2003) and react negatively to group work (Phipps et al., 2001), or desire to work independently (Gotschall and Garcia, 2008), some disciplines have begun to include skills related to teamwork and leadership in their curricular goals, including those with clear relevance to Neuroscience (American Psychological Association, 2013). This suggests that increased efforts to promote student ability to work within teams in a way that is inclusive, productive, and supportive of learning is warranted.

Considerations
Bloom's taxonomy was used in the scaffolded worksheets as a way to conceptualize the process of student learning and understanding and to help students understand "types" of questions. It allowed the faculty to explain that some worksheet and exam questions would require "deeper" or more extensive understanding of the material, and the ability (or lack thereof) of students to answer those questions on the worksheets indicated the need for further study and practice, and/or the need to seek instructor support. Previous work suggests that students align their preparation with expected assessment (Crowe et al., 2008). While there is the potential for increased transparency in assessment, such as described here, to decrease self-regulated learning and lead to increased reliance on the teacher and less independence; strategies have been delineated to minimize such a result (Balloo et al., 2018); these strategies again emphasize scaffolding and inclusivity. Future work could use Bloom's taxonomy to a more significant degree; but the desire to maximize the amount of in class time to practice and review drove the decision to only introduce the basics of Bloom's taxonomy.

The scaffolded worksheets aimed to increase metacognitive practices and self-regulated learning in students, yet this was not explicitly assessed in the current approach. Metacognition has been linked to student performance (Vukman and Licardo, 2010), problem solving ability (Sandi-Urena et al., 2012), thinking (Otero and Gray, 2008), and self-efficacy (Clauss and Geedy, 2010), yet there is still much to be learned to improve understanding about how to promote metacognition in the classroom (Tanner, 2012; Stanton et al., 2015, 2019). The current approach emphasized metacognitive knowledge and the instructor tried to prompt metacognitive monitoring via in-class review of worksheets, but the course did not explicitly address or attempt to measure metacognitive control; this could provide additional benefit (Stanton et al., 2015; 2019). In addition, there are examples of courses that extensively integrate metacognition into both design and assessment (Tanner, 2012). The current study did not specifically evaluate whether the worksheets increased metacognitive practice.

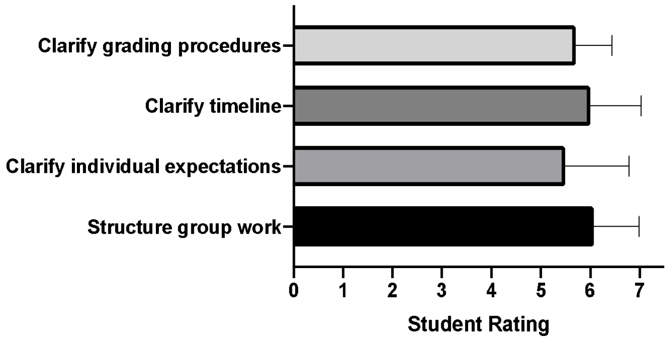

Figure 3. Student rating of degree to which worksheets helped various items in a Cognition course, Likert scale 1-7 (1=never, 4=sometimes, 7=always). Average ± SEM is shown, n=37 students.

Anecdotal evidence such as student questions, student reflection on their understanding, and requests for clarification of things they did not understand and additional practice opportunities suggest some metacognition was likely occurring. It would be useful to understand how metacognitive processes might mediate possible relationships between assessment practice and exam or course performance to emphasize the degree to which metacognition is an important component of active learning techniques.

Among their many benefits, active learning approaches can also serve to create a more inclusive classroom (Snyder et al., 2016). The in-class scaffolded worksheets are an example of frequent, low-stakes, formative assessments that may lead to gains among underrepresented groups (Haak and Freeman, 2011; Ballen et al., 2017; Theobald et al., 2020). These worksheets were also used to explicitly convey to students the types of questions that would be used as criteria for measuring content knowledge and understanding on exams, and students were given multiple opportunities for practice with instructor feedback and opportunities to discuss grading criteria with the instructor. Both of these approaches are thought to increase inclusivity in the classroom (Crowe et al., 2008; Balloo et al., 2018; Penner et al., 2018). Research suggests that expecting higher level skills, such as those associated with questions and assignments that expect application, analysis, and evaluation, in the absence of formative assessments to support the development of such skills may reveal gaps in preparation and disadvantage those students with less experience or preparation with these sorts of assignments (Balloo et al., 2018, Penner et al., 2018). Shared group worksheets were also used to improve transparency and make grading criteria more explicit, and group learning experiences are also among the approaches that lead to gains among underrepresented groups (Lorenzo et al., 2006; Haak and Freeman, 2011; Ballen et al., 2017). The in-class and shared group worksheets also sought to provide support for students as they made progress towards more advanced levels of thinking and performance and aimed to prompt metacognition, which can promote inclusivity as well (Quinones-Magalhaes and Hane, 2020).

However, despite support for the use of active learning as a means to improve inclusivity, recent reports do suggest that active learning alone may not be sufficient to achieve inclusivity (Hood et al., 2020), and that caution should be used in the implementation of such techniques (Dewsbury et al., 2017; Quinones-Magalhaes and Hane, 2020; Theobald et al., 2020). The degree to which the approaches to active learning are scaffolded and supported may be critical to their success (Hood et al., 2020; Theobald et al., 2020). Dialogue between students and faculty may also be critical to success (Dewsbury et al., 2017). The classroom environment can play an important role in inclusivity (Johnson, 2019), and faculty should be appropriately supported in their attempts to utilize active learning procedures to avoid unintentional negative effects (Quinones-Magalhaes and Hane, 2020; Theobald et al., 2020). Active learning may also cause anxiety in some students (Brigati et al., 2020), which could be detrimental to their performance. Yet faculty can likely do much to reduce the potential impact of student anxiety and differential preparation on performance (Owens et al., 2017), and there are many other strategies for using active learning in a way that maximizes the inclusive nature of the classroom (Dewsbury et al., 2017; Johnson, 2019; Quinones-Magalhaes and Hane, 2020).

The development and implementation of the strategies addressed here did take considerable time and effort on the part of the instructor, and many faculty may not receive time or compensation for such curricular efforts. Faculty workload has been cited as a possible reason why active learning is not used in a more universal fashion (Kuh et al., 2008; Kuh et al., 2017; Ujir et al., 2020). In fact, the inconsistent adoption of active learning strategies may disadvantage some students (Kuh et al., 2017) and may be a result of insufficient institutional support for faculty to design, develop, implement, and assess such work (Ujir et al., 2020). This lack of institutional investment undermines the ability of educators to provide what is becoming widely acknowledged as a more effective, more equitable education. Faculty efforts to engage in active learning techniques in spite of limited resources are admirable. More significant acknowledgement of the importance of such work at educational institutions, through their educational policies and priorities, could prompt more significant, systemic change (Taylor, 2017).

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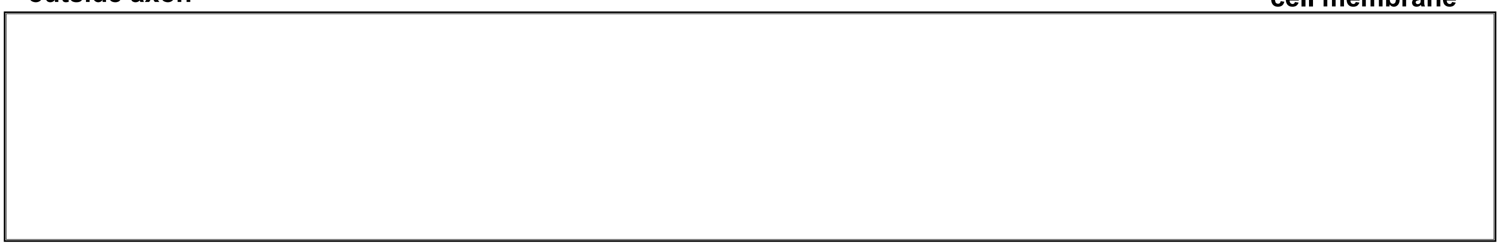
APPENDIX 1
BEHAVIORAL NEUROSCIENCE WORKSHEET

Name:

Remember - these worksheets give you a good sense of the sorts of questions that will be present on exams. They also help you evaluate your knowledge, understand where you need more preparation, direct your efforts in continuing to prepare for exams, and practice taking the exams.

Q1-3 are "remember" types of questions- you can memorize, then recall this information

1. Imagine the image below represents a portion of the axon hillock. Draw the ions and channels that we discussed that are important for action potentials. Indicate the concentrations of each ion.



2. Where would sodium move, if it could, and why (list ALL reasons why)?

3. Where would potassium move, if it could, and why (list ALL reasons why)?

For Q4, we've moved to testing your understanding- you have to understand why ions move to figure out the movement of chloride.

4. We discussed the ion chloride in class but we didn't discuss where it would move. Once you understand the rules about ion movement, IF you remember chloride concentrations, you should be able to figure out where chloride would move and why. Describe where chloride would move and why (list ALL reasons why).

For Q5-6, we've moved to an "apply" level- we're adding new information and asking you to apply it to a situation that you've grown to understand.

5. Let's pretend we've added new ion, neuronium, to the OUTSIDE of the neuron ONLY at a concentration of 100μM. It is NEGATIVELY CHARGED. Once added, where would it move and why (list ALL reasons why)?

6. We also talked about action potentials- how the charge inside the neuron goes from negative to positive and back to negative/rest.

a. At the peak of the action potential, where does Cl- want to move based on concentration gradient? Why?

b. How about based on charge gradient? Why?

c. Would Cl- move more dramatically if its channels are opened when the neuron is at rest, or if its channels are opened when the neuron is at the peak of the action potential? Why?

Q7 is at the "analyze" level. You are asked to explain a novel situation given what you understand about a neuron at rest. You can compare the new situation to the old, identify similarities and differences, come up with explanations, use your understanding to evaluate those explanations, and choose the best.

7. You are recording from the inside of a neuron that is sitting at rest. Your colleague adds a drug that opens ONLY one ion channel, but she doesn't know which channel. You watch as the inside of the neuron gets MORE negative. Make your best guess: what ion channel does the drug target? Explain the reasoning behind your choice.

APPENDIX 2
STRUCTURED GROUP PROJECT WORKSHEET

A few notes for colleagues using this worksheet: 1) I use google docs, 2) It may be easier to create the docs yourself, share, and verify in class that students have access, 3) A single doc for the whole class where each group has their own "working section" that is clearly labeled with group names and numbers can work – this makes tracking easier. You'd want different research topics between groups to limit risk of cheating, 4) There are some dates and details that are specific to the project that need to be updated each term, 5) I generally use groups of 4-6 depending on course enrollment.

THE PROJECT:
Learning goals:
1) develop your understanding of research in cognition through design of an experiment that adequately tests a novel research hypothesis
2) develop your oral and written communication skills and ability to work in teams by engaging as an active and communicative group member that contributes to the process and the final group presentation.

Assessment: Your group work will culminate in the presentation of a novel experimental idea in cognition that includes 1) an introduction, 2) detailed methodology, 3) hypothetical results, and 4) discussion of drawbacks, potential confounds in your design, and ways to remedy those issues, as well as relevance to the broader field. Please refer to the detailed assignment information and rubric sheet posted on D2L for more information.

This shared document will guide you through the group work process, facilitate equal contributions to the assignment, allow me to grade your individual contributions (points are specified throughout), and communicate and give you feedback on your progress outside of class (though we will also have time for that during class sessions).

<u>GROUP MEETING 1 (in class) (5pts)</u>
1. Verify that you can all access the shared doc. Report any issues to Dr. B. Designate someone as notetaker for today and list that person's name here: __________________________. Notetakers are responsible for recording group discussions, decisions, and process, as well as responding to any specified requests in the document. The role of notetaker should be rotated between group members.

2. Read the information above ("THE PROJECT"), the rubric on D2L, and the entirety of the steps outlined below. Ask Dr. B any questions regarding the nature or requirements of the assignment or the group work.

3. Choose TWO areas of interest from the topics we discussed in this course. Notetaker, annotate this discussion- initial suggestions, agreement/disagreement, limitations, etc. As you aim to settle on 2 areas, if there are more than 2, try to find overlap between them (i.e., interests in language and memory, could mean research on memory for verbal information). Communicate your areas to Dr. B and list your final areas (note: even if you all agree on a first area, list a second).

AREA 1:
AREA 2:

3. Set the time for your next meeting – I'd recommend at least 45-60 min in length (must happen prior to _______)

TIME AND DATE: _______________ CAN ALL ATTEND? Y N
***If no, how will non-attending members contribute? Be SPECIFIC - this should involve ~ 45+ min of work in addition to the work described below under "your next tasks".*

<u>Your next tasks:</u> *1) BEFORE GROUP MEETING 2*, each of you should come up with two possible IV/DV combinations based on your chosen research areas (you can use one or both). Each student should post them here PRIOR to your next meeting **(5pts)**. 2) Attend the next meeting.

<u>GROUP MEETING 2 (outside of class time, 5pts)</u>
1. Designate a NEW notetaker: ______________________________. Anyone absent (please list)?

2. Review the IV/DV combinations. Work to operationally define the IVs and DVs as a group (i.e., don't just list "memory", specify the exact memory test and understand it). You may have to search the literature. Notetaker: take notes on this process- how does the group work to make them operationally defined?

3. Vote on what IV/DV combination you would like to start with (again, this should be well defined operationally). Remember, this needs to be novel (you might come back to the other options if your original is NOT novel).

IV: DV:

4. Establish novelty. The primary way to establish novelty is search, search, search and then to read, read, read. If you have time remaining, start that reading now, and record article authors/titles.

4. Before leaving: Set the time for your next meeting:

TIME AND DATE: _______________ CAN ALL ATTEND? Y N

**If no, how will non-attending members participate?*

Your next task: *1) BEFORE MEETING 3: Each student should post the title and authors of 3 articles relevant to the topic to help establish novelty (ones you found as a group in class don't count). Write a 3-sentence description of each* ***(5pts)****: how is it similar to your topic and how is it different (it needs to be different in order for YOUR idea to be novel)?*

GROUP MEETING 3 (in class) (5pts):

1. Designate a NEW notetaker: ___________________________. Anyone absent (please list)?

2. Discuss your sources; each student should take a few minutes to describe their sources. Notetaker, please take notes. The goal of this discussion is: a) given these sources, do we think our idea is novel? b) if yes, talk to Dr. B. c) if no, can you make it novel? Hint: I can probably help!

3. You have a topic: hooray! Time for MORE reading and research. Reminder: your job is to give a presentation where you provide background information, have detailed methodology, present hypothetical results, and discuss those results (drawbacks, possible confounds, solutions, degree of relevance to related topics, etc.). I would rely HEAVILY on the rubric; it lists everything you need to do.

Also remember, you've done some of this work already! The sources you've already found can help with this, and THOSE sources have reference lists of additional sources.

4. So, review the rubric together. Now, brainstorm a task list together. Notetaker: write your brainstorming results below.

5. Now, divide and conquer. Personally, I like assigning 2 people to each main task so they can discuss with one another and share resources and ideas, and then come back to the group with more cohesive plans and ideas. This work should be done PRIOR to the next group meeting, and notes should always be taken on that process.

6. Before leaving: Set the time for your next meeting:

TIME AND DATE: _______________ CAN ALL ATTEND? Y N

**If no, how will non-attending members participate?*

GROUP MEETING 4 (out of class) (5pts):

1. Designate a NEW notetaker: __________________________. Anyone absent (please list)?

2. Progress updates! Each person should talk about their progress on the tasks they were given above, and this discussion should be documented:

3. Evaluate as a group: how is the progress? What parts need work? What's well developed? Start with some general discussion, but then generate a specific task list of who is doing what, (i.e., "work on methods" is not specific enough, but "find sources to see if the Dichotic listening task has been used with children" is specific and appropriate). Assign these tasks to group members.

4. What's the process from here on out? Come up with a plan as a group and translate this into a timeline. Work backwards from your final due date and add in intermediary due dates with subtasks that also have due dates. List the timeline below; who is doing what and when? I'd highly recommend at least one more group meeting, but that is not required. What IS required is continued contribution to the group and sharing your progress on the shared google doc below as you complete these tasks.