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ARTICLE
Call for collaboration: Drafting a concept inventory for assessing neuroscience courses and curriculum

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Neuroscience draws upon concepts from biology, chemistry, computer sciences, philosophy, physics, and psychology, to study the nervous system. Growth of this field is evidenced by the expansion of neuroscience programs, all of which undergo accreditation to ensure educational quality. Content knowledge is commonly assessed for accreditation, but a standardized instrument measuring neuroscience content knowledge is yet to be developed. To address this gap, we are leveraging the eight neuroscience core concepts identified by Chen and colleagues to design a Neuroscience Concept Inventory (NCI). As a first draft, we generated a 57-multiple choice question tool and distributed among students in an introductory neuroscience course and declared neuroscience majors at a large public R1-institution. Item discrimination scores determining the quality of items ranged from 0.65-0.10, with 48 falling within acceptable range (>0.20). Alpha reliability scores determining reliability of items within a core concept ranged from 0.77-0.51, with 4 falling within acceptable range (>0.70). To exemplify the utility of a NCI, we present an accreditation report case study. Utilizing the NCI draft we demonstrate learning gains in an Introduction to Neuroscience course and among neuroscience majors. Our project sets the groundwork for the continued development of a reliable tool that facilitates content knowledge assessment of neuroscience programs and courses. The interdisciplinary nature and diversity of neuroscience programs present a major challenge to the development of a comprehensive content knowledge tool. Thus, we share this first draft as a call to the neuroscience community to join us to iteratively improve the instrument through collaboration and feedback. Those wishing to collaborate for tool development, please fill out this Qualtrics Form

Key words: Accreditation, Assessment, Concept inventory, Core concepts, Neuroscience

Core concepts and competencies within a scientific discipline are critical tools used to shape curricula and improve undergraduate STEM education. Core competencies identify key skills and training that students should gain from an academic program. Core concepts, on the other hand, are fundamental, discipline-specific ideas that scientists and educators agree are essential for students to learn and understand (Woodin et al., 2010). The Society for Neuroscience (SfN), which is the largest professional organization in the field (>37,000 members), outlined five overarching core competencies for neuroscience undergraduates: conceptual knowledge, analytic & scientific thinking, rigorous & responsible conduct of research, communication skills, and individual development and professionalism (Anon, n.d.). Neuroscience core concepts, highlighting the essential facts and principles in the field, however, were lacking until recently. This is in part due to newness of the field and the highly interdisciplinary nature of neuroscience, which employs experimental approaches from biology, chemistry, computer science, philosophy, physics, and psychology.

To overcome these hurdles and identify comprehensive core concepts to guide undergraduate neuroscience curricula, a team of neuroscientists took a community-derived, empirical approach (Chen et al., 2022, 2023a). The iterative process, which outlined eight core concepts, included a nationwide survey and a working session with over 100 neuroscientists and was modeled on the physiology core concepts creation process (Michael and McFarland, 2011). Now, neuroscience educators can leverage the eight concepts as another tool to help design, improve, and assess curricula nationwide.

Numerous educator groups within a variety of STEM fields have leveraged their core concepts to create assessment tools called concept inventories. The goal of a concept inventory is to assess students' understanding and knowledge of the essential principles and facts in the field. Concept inventories are also valuable because they can reveal gaps in a curriculum, the prevalence of misconceptions, and even evidence of bias (Hestenes et al., 1992; Klymkowsky and Garvin-Doxas, 2008; Rennpferd et al., 2023). Concept inventories are also often tailored to a particular subfield or concept within a discipline (Kalas et al., 2013; Perez et al., 2013; Price et al., 2014; Newman et al., 2016; McFarland et al., 2017). For example, the first concept inventory tool published in 1992, the Force Concept Inventory, assessed student understanding of Newtonian principles in physics. A more recent neurophysiology tool assesses student understanding of ion movement and membrane potentials (Cerchiara et al., 2019). Given the very recent development of core concepts in neuroscience, no concept tool inventories exist yet for neuroscience curricula. Development of such tools, however, is warranted given the rapid growth of the discipline over the last 50 years

(Altimus et al., 2020) driven by incredible technological advances and investment in brain research (Anon, n.d.). Growth in neuroscience education programs nationwide has occurred in parallel, with the number of new degree programs exploding from 104 in 2006 to 221 in 2018 supporting roughly 7000 majors (Gaudier-Diaz et al., 2019; Ramirez, 2020).

Given the value of concept inventories and the lack of such tools in neuroscience, we've started a multi-phased process for creating a concept inventory based on the eight recently identified core concepts (Chen et al., 2022, 2023a). We've modeled our approach after the multi-step process used for development and validation of the microbiology concept inventory (MCI; Paustian et al., 2017). The abbreviated eight core concepts include Communication modalities, Emergence, Evolution, Gene-environment interactions, Information processing, Nervous system functions, Plasticity, and Structure-function relationship. We used these concepts and their underlying principles, as a scaffold to create a 57-multiple choice draft tool. Further, we piloted the draft tool in multiple sections of an Introduction to Neuroscience course and with students at all different stages of their undergraduate neuroscience major at a large public R1 institution.

Here, we share the first draft of the Neuroscience Concept Inventory (NCI; Supplemental Table 1) and our plans for a collaborative and multi-institution multi-phased development of the tool. The broad utility of concept inventories and the lack of such a tool in neuroscience inspired us to leverage the newly published neuroscience core concepts to draft the NCI. Our goal is to share the draft along with our plans for the multi-phased development of the tool as a call to the neuroscience community to collaborate. To date, we have presented the draft tool and our multi-phased process to educators at the 2024 Neuroscience Teaching Conference in Winston-Salem, NC. From this meeting, at least 17 neuroscience educators representing 17 different institutions across 11 states expressed interest in joining the NCI tool development effort. Together, we hope to create a final, fully evaluated and validated NCI tool that can be used across diverse institutions to assess and improve neuroscience education.

We also share here our initial concept inventory assessment and an example of how it can be used. To evaluate the reliability of our tool and the internal consistency of questions used to test each core concept, we used Cronbach's alpha. To determine how well questions discriminated between high- and low-performing students and ensure questions encompassed a range of difficulties, we used item discrimination and item difficulty, respectively. Then, to illustrate the potential of the tool, we report a case example of how we used the tool for the accreditation of our neuroscience program. The Southern Association of Colleges and Schools (SACS) commission on colleges assures educational quality and improves the effectiveness of its member institutions through accreditation. Our five-year accreditation assessment plan aligns with the key competencies outlined by SfN, which includes assessment of student knowledge. Here, we show data illustrating how this NCI draft tool and future fully validated versions could be used for accreditation purposes.

MATERIALS AND METHODS

Concept Inventory Development

Leveraging the Neuroscience Core Concepts (Chen et al., 2022, 2023a), we developed a 57-multiple choice question assessment tool (Supplemental Table 1). When developing questions, we utilized the general descriptions provided by Chen et al. (2022) as a main resource. For questions on core concepts: Evolution, Gene-environment interactions, Plasticity and Structure-function relationship, we also utilized the initial unpacking outline described by Chen et al., (2023b). Indeed, the more comprehensive information allowed for the development of more focused questions.

Questions for the NCI draft were either pulled from an exam question bank for an Introduction to Neuroscience course, written by authors, or developed with the help of ChatGPT (Open AI, 2023). Over the past few years, instructors of the Introduction to Neuroscience course have built a question bank, like the ones commonly published with textbooks. These questions align with the course learning objectives and content from the Neuroscience Exploring the Brain textbook (Bear et al., 2016). From here, 3 questions were directly included in the NCI draft. Another 25 questions were written by the authors to evaluate concepts that were not represented in the question bank.

To incorporate questions that directly aligned with the core concepts, we used ChatGPT (Open AI, 2023). For this, the description of each neuroscience core concept from Chen et al. (2023) was provided as a prompt, and ChatGPT was asked to generate multiple choice questions to probe student knowledge of the description. The ChatGPT-generated questions and answer choices were then edited to correct grammar, reduce redundancy with other questions and answer choices, improve clarity, and ensure accuracy. A total of 29 questions were designed with the help of ChatGPT.

Once compiled, the 57 questions were reviewed and approved by all authors. During the review process, minor wording revisions were conducted to increase clarity. Educators interested in the draft tool can contact the corresponding author (gaudier@unc.edu).

Data Collection

Introduction to Neuroscience

Students enrolled in the Introduction to Neuroscience course during Fall 2023 completed the 57-question NCI draft before and after completing the course as an extra credit assignment. By the first week of class all students enrolled in a section of the introductory course were asked to complete the tool, which was presented as a test in their Canvas site. On the last day of class, students received a link to a Qualtrics survey, in which all items from the tool were presented to them. Out of the 190 enrolled students, 75 completed both the pre- and post-course assessments. Some students may not have participated because they did not need the extra credit at the end of the semester. Students in the Introduction to Neuroscience course ranged

Core Concept	Number of questions	Range for item discrimination	Cronbach's alpha
Communication modalities	9	0.10-0.39, 6 values >0.2	0.513
Emergence	8	0.18-0.55, 7 values >0.2	0.650
Evolution	7	0.2-0.62	0.707
Gene-environment interactions	7	0.13-0.65, 6 values >0.2	0.766
Information processing	6	0.20-0.54	0.657
Nervous system functions	6	0.12-0.50, 3 values >0.2	0.547
Plasticity	6	0.31-0.55	0.719
Structure-function relationship	7	0.21-0.63	0.764

Table 1. Core Concept Inventory Assessment. Item discrimination scores, indicating the quality of each item, ranged from 0.65-0.10, with 48 in the acceptable range (>0.20). Cronbach's alpha, indicating internal reliability of items within a core concept, ranged from 0.77-0.51, with 4 in the acceptable range (>0.70).

from first years to seniors and included Neuroscience majors and non-majors.

Neuroscience Majors
All declared neuroscience majors (~950 students) received an invitation to complete the NCI draft. The survey was distributed to all neuroscience majors via a listserv email. Additionally, course instructors of upper-level neuroscience courses were asked to distribute the survey and encouraged to offer extra credit for completion. A total of 111 students with a declared neuroscience major participated. This data was then combined with the post-course assessment data from students in the Introduction to Neuroscience course, for a total sample size of 186.

Concept Inventory Assessment
To allow for a more robust analysis of the NCI draft tool, all student responses were downloaded and combined (N = 186). To assess the quality of each question, an item analysis was conducted using the R package *sjplot* (Lüdecke et al., 2024). Student responses to each question were dichotomized to reflect if the answer choice was correct or incorrect. No partial credit was given on "Select all that apply" questions. One question assessing Structure-function relationships should have been coded as "Select all that apply" on Canvas/Qualtrics, but instead students were restricted to select only one answer choice; as such this question was removed from the item analysis. Item discrimination index (DI) was calculated for each question and interpreted with the following parameters: ≥ 0.35 is excellent, 0.2 - 0.34 is acceptable, < 0.2 is poor (Bardar et al., 2006; Ananthakrishnan et al., 2021). Item difficulty, or the percent of students who answered that item correctly, was also calculated for each question. A range of item difficulty within each concept category is ideal. Cronbach's alpha was calculated for each core concept to assess the internal cohesion of the questions pertaining to each core concept. A Cronbach's alpha ≥ 0.70 is determined as good (Bardar et al., 2006; Tavakol and Dennick, 2011; Paustian et al., 2017).

Concept Inventory Use
Evaluation of an Introduction to Neuroscience Course
Data from students in the Introduction to Neuroscience course were downloaded and matched using the student's personal identification number. A paired-samples t-test was conducted on the pre- and post-course assessment mean performance to determine overall learning gains. Additional paired-samples t-tests were conducted to assess learning gains for each of the eight neuroscience core concepts. Analyses were run in R.

Evaluation of a Neuroscience Program
Post assessment data from students in the Introduction to Neuroscience course and data from neuroscience majors were exported from Qualtrics, combined, and analyzed. Mean correctness for each of the eight neuroscience core concepts was calculated. The data were sorted by year in college (e.g., 1, 2, 3, and 4) and the number of completed neuroscience courses (e.g., 0, 1, 2, 3, 4, or 5+). Analysis of variance (ANOVAs) with Tukey's post-hoc test was conducted to evaluate significant differences based on year in college and number of completed neuroscience courses. Additionally, a Pearson correlation was conducted to evaluate the relationship between the overall mean correctness (i.e., neuroscience content knowledge) and the number of completed neuroscience courses. These analyses demonstrate how the NCI draft can be used for evaluation of a neuroscience program, as in for accreditation purposes. Analyses were run in R.

RESULTS
Concept Inventory Assessment
Item discrimination and item difficulty analysis
For each item in the NCI draft, an item discrimination index (DI) and item difficulty were calculated (Supplemental Table 1). In accordance with the item discrimination values, 32 items were excellent (DI≥0.35), 16 were acceptable (0.35>DI≥0.20), and 8 were poor (DI<0.20). Overall, item difficulty ranged from 0.09-0.92.

Internal reliability analysis
For each of the eight neuroscience core concepts, internal cohesion among items was determined using Cronbach's alpha (Table 1). In accordance with the reliability analysis, there is cohesion among items assessing Evolution (α=0.707), Gene-environment interactions (α=0.766), Plasticity (α=0.719), and Structure-function relationship (α=0.764), but not for Communication modalities (α=0.513), Emergence (α=0.650), Information processing (α=0.657), and Nervous system functions (α=0.547).

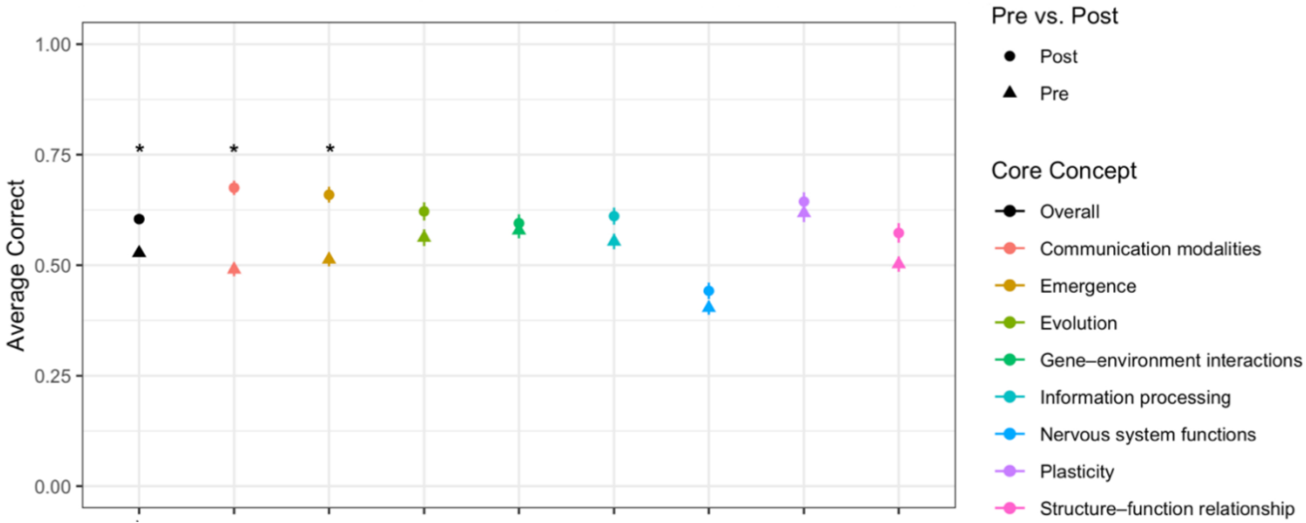

Figure 1. Evaluating an Introduction to Neuroscience course. Pre- and post-course mean correctness for each of the eight neuroscience core concepts. When comparing correctness, there were significant increases (*) overall (t (545)=-4.539, p<0.05) and for the communication modalities (t (74)=-5.15, p<0.05) and emergence (t (70)=-4.86, p<0.05) core concepts. Total sample size (N) ranges from 75-66.

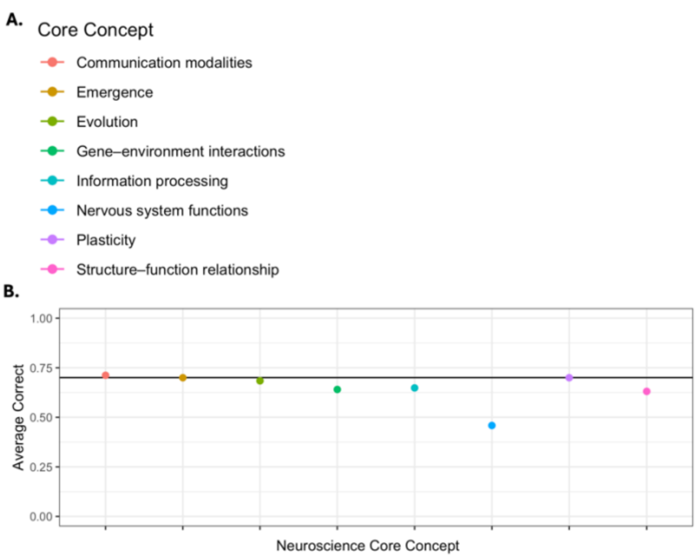

Figure 2. Evaluating a Neuroscience Program. (A) Figure legend. (B) Mean correctness for each of the eight neuroscience core concepts.

Concept Inventory Use

Evaluation of an Introduction to Neuroscience Course

For each of the eight neuroscience core concepts, pre- and post-course mean correctness were calculated. When comparing overall mean correctness, a significant increase was determined (t (545)=-4.539, p<0.05; Figure 1).

Despite a numeric increase when comparing pre- to post-course mean correctness values for all of the neuroscience core concepts, significant learning gains were only apparent for the Communication modalities and Emergence core concepts; t (74)=-5.15, p<0.05 and t (70)=-4.86, p<0.05, respectively.

Evaluation of a Neuroscience Program

For each of the eight neuroscience core concepts, mean correctness was calculated. Neuroscience majors scored highest on Communication modalities (0.71), Emergence (0.70), Evolution (0.68), and Plasticity (0.70), and lowest on Nervous system function (0.46; Figure 2B).

When examining mean correctness for each of the neuroscience core concepts per year in school, there were significant differences between the groups (F (3)=10.47, p<0.05; Figure 3B). Specifically, students in year 4 perform significantly better than students in years 1, 2 and 3 (p<0.05, for all). Further, the mean correctness per core concept for students in year 4 surpasses 70% correctness for all core concepts, except Nervous system functions.

When examining mean correctness for each of the neuroscience core concepts per number of completed neuroscience courses there were significant differences between the groups (F (5)=10.43, p<0.05). Post-hoc analyses reveal that students who have completed 2 or 4 neuroscience courses perform significantly better than students who have completed 0 or 1 neuroscience courses (Figure 3C). Further, when determining accuracy, students who have completed two, three, four, or five+ neuroscience courses surpass 70% correctness for at least one of the core concepts.

A significant positive linear relationship between the overall mean correctness on the NCI draft tool (i.e., Neuroscience content knowledge) and the number of completed neuroscience courses was also determined (r (1314)=0.14, p<0.05; Figure 4).

DISCUSSION

Findings

Our study contributes to neuroscience education by addressing the need for a standardized tool to assess conceptual understanding. Core concept inventories are widely used across many disciplines to assess students' understanding of fundamental concepts, identify misconceptions, and evaluate the effectiveness of instructional methods. We demonstrate use of our inventory for accreditation purposes as well as for assessing curriculum design (Furrow and Hsu, 2019; Rennpferd et al., 2023).

While we are excited to share this draft with the neuroscience community, we acknowledge its many limitations. We hope to continue this tool's development in a multi-phase process (see Multi-Phase Development Plan) and share it as a valuable resource for educators and institutions seeking to evaluate and improve neuroscience education. Additionally, since the NCI tool is in draft phase, we hope to recruit collaborators to assist in continued tool improvement, evaluation, and validation for the neuroscience community.

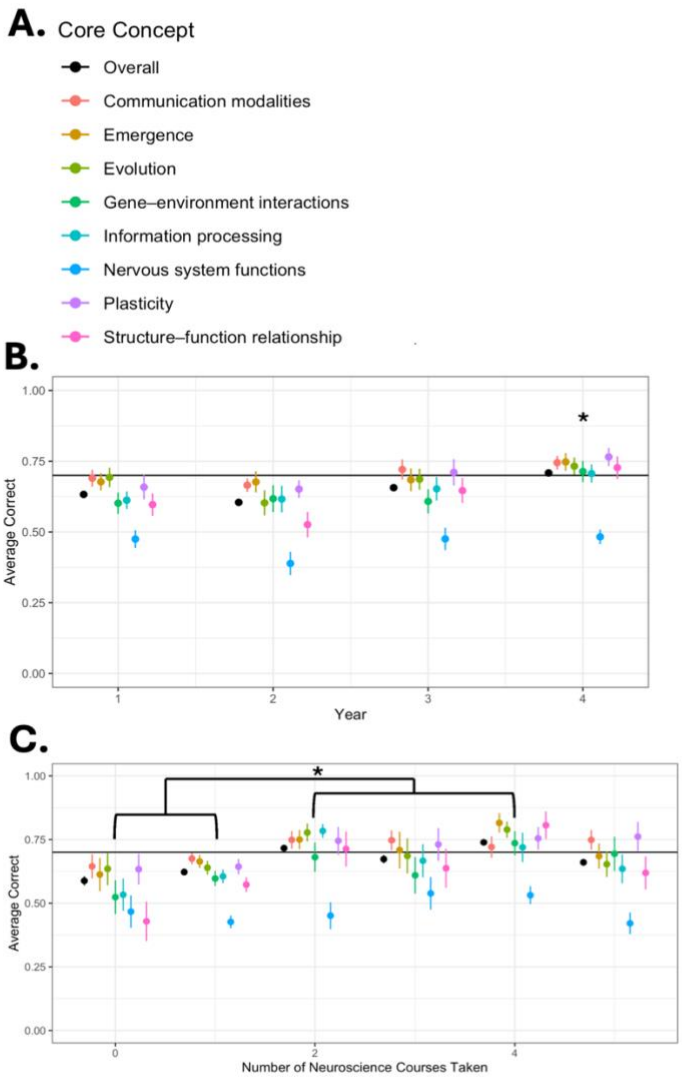

Figure 3. Evaluating a Neuroscience Program. (A) Figure legend. (*B*) Mean correctness for each of the eight neuroscience core concepts per year in college. With all core concepts combined, there are performance differences: $F(3)=10.47$, $p<0.05$. Tukey's post-hoc tests showed that students in year 4 significantly differ from students in years 1, 2, and 3 (*). (C) Mean correctness for each of the eight neuroscience core concepts per number of completed neuroscience courses. With all core concepts combined, there are performance differences: $F(5)=10.43$, $p<0.05$. Tukey's post-hoc showed that students who have only completed 0 or 1 neurosciences courses significantly differ from students who have completed 2 or 4 neuroscience courses (*).

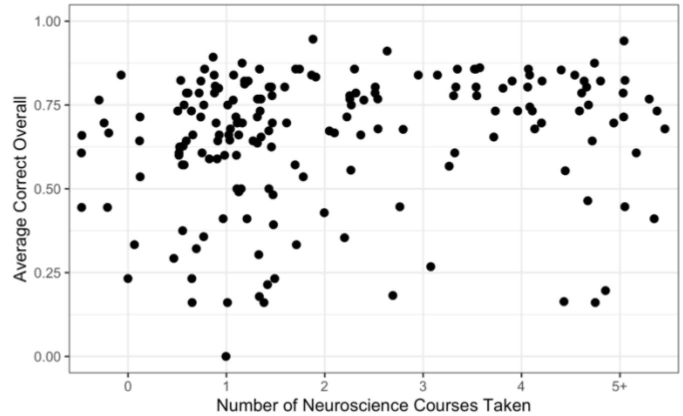

Figure 4. Evaluating a Neuroscience Program. Positive linear relationship between the overall mean correctness and number of completed neuroscience courses ($r(1314)=0.14$, $p<0.05$).

Validity and Reliability of the NCI

The item discrimination index for most items in the NCI draft tool fell within the desirable range of ≥ 0.20. Generally, an item discrimination index of ≥ 0.35 is excellent, 0.2 - 0.34 is acceptable, <0.2 is poor. Across the 57 items, discrimination indices ranged from 0.10 to 0.63, with an average of 0.39, suggesting a good level of differentiation between test-takers' abilities. Nine questions fell below the 0.2 range indicating that these questions were answered correctly by both high-performing and low-performing students. These 9 questions will need to be edited to effectively assess the concept. Thirty-one questions fell in the excellent range. Seventeen questions fell in the acceptable range and may need revision for improvement. Notably, 50% of the questions related to the core concept of Nervous system functions fell below the acceptable range of 0.2, indicating a need for revising questions for this category.

The item difficulty for the core concepts in the NCI draft varied widely, ranging from 0.09 to 0.92, with an average difficulty of 0.66 for Communication modalities, 0.69 for Emergence, 0.68 for Evolution, 0.63 for Gene-environment interactions, 0.64 for Information processing, 0.46 for Nervous system functions, 0.69 for Plasticity, and 0.61 for Structure-function relationship. Overall, most items fell within an acceptable range of difficulty. The item response theory states that an acceptable range is about 0.2 to 0.8 (Bardar et al., 2006). Out of 56 questions, 5 (8.93%) were below 0.2, and 15 (26.79%) were above 0.8. The majority are acceptable within the range (64.29%), and items outside this range will be revised in phase one of the NCI tool development. The item difficulty highlights the overall effectiveness of the NCI draft tool in assessing core concepts at an appropriate difficulty level, however, questions falling outside of the desired range will need to be improved. Many items related to Nervous system functions had a low average difficulty, indicating that these items are too challenging and need revision. Additionally, questions that required students to "Select all that apply" had lower item difficulty values regardless of core concept. These questions will be rewritten so that they are no longer "select all that apply" and to ensure they align with the concept and are of an appropriate difficulty level.

A Cronbach's alpha value greater than 0.7 is desirable (Tavakol and Dennick, 2011), as it indicates that the test addresses different constructs and delivers reliable scores. We demonstrate that for four of the eight core concepts (Evolution, Gene-environment interactions, Plasticity, Structure-function relationship) the Cronbach's alpha value indicated a reliable concept inventory. The remaining four core concepts (Communication modalities, Emergence, Information processing, and Nervous system functions) demonstrated Cronbach's alpha scores slightly below 0.7 (Table 1), which suggests that the items within each of these concepts are not sufficiently correlated with each other. There may be several reasons for this, such as ambiguously worded questions or a small number of items contributing to the scale. These will be edited and addressed in phase one of our NCI tool development (see Multi-Phase Development Plan). Further, at later stages of development we will run an Exploratory Factor Analysis to better evaluate patterns of correlation between the items (i.e., questions) to facilitate item grouping and reduction, while also assessing validity and reliability.

Assessment of Student Learning Outcomes

In the Introduction to Neuroscience course, students demonstrated increased learning gains overall when comparing pre- and post-course NCI assessments. Particularly, two core concepts, Communication modalities and Emergence, demonstrated the largest learning gains (Figure 1). It is encouraging to see the tangible progress our students have made, which suggests that the course effectively facilitates deeper comprehension and engagement with fundamental topics. Additionally, through the utilization of this tool, we identified gaps within our Introduction to Neuroscience course. This valuable information allows us to place a larger emphasis on core concepts that may not have been properly addressed within the course.

In our evaluation of the neuroscience program, we found that students generally performed well across most core concepts (Figure 2A). While students in their first year initially demonstrated below-average mean correctness across all eight core concepts, by the end of their fourth year, students improved significantly with seven of the eight core concepts surpassing the mean correctness threshold of 70% accuracy (Figure 3B). Interestingly, students who completed either two or four neuroscience courses demonstrated the highest outcomes across all core concepts (Figure 3C), indicating the effectiveness of our program in offering a variety of courses to ensure a thorough grasp of key principles in neuroscience. Our program effectively addresses most core concepts, however Nervous system functions emerged as the lowest scored core concept. Poor performance on the Nervous system functions items may be due to limitations in the NCI tool, specifically related to reliability and discrimination, rather than deficiencies in course coverage of this material. Three of the six nervous system functions items had a poor discrimination index and the reliability score for this core concept was below the acceptable range; thus, conclusions must be taken with caution. Still, the present findings may suggest a potential challenge area for students and indicate an aspect of the curriculum that requires further attention. Altogether, via the use of the NCI draft we were able to document significant learning gains in the Introduction to Neuroscience course and as neuroscience majors engage with the curriculum, which was critical for our accreditation report. Further, it illustrates what can be assessed and explored once a reliable NCI is developed.

Limitations

Despite the utility of our current NCI assessment tool, it is important to address several limitations. One issue is the lack of randomization in the presentation of questions to students in our survey, coupled with non-mandatory responses for all questions. As a result, students tended to respond to earlier questions more frequently than later ones, meaning that some core concept questions have many responses while other core concepts questions have fewer as students failed to fully complete the survey. Lack of student motivation does weaken the results and make it difficult to draw strong conclusions from the data. Furthermore, the tool was administered to students for either extra credit or without any incentive, potentially affecting the motivation and reliability of their responses. For future phases of the tool, we will incorporate randomized question presentation, trap questions, and appropriate distractors to ensure the quality of the data (Haladyna et al., 2002; D'Avanzo, 2008; Richardson, 2012).

Additionally, as discussed earlier, many items fell outside of the desirable analyses range and these items will be edited in future phases of tool development. Analyzing data based on gender category, first-generation status, race/ethnicity can improve this tool and reveal biases (Dewsbury and Brame, 2019). By conducting these additional analyses, we can refine the tool, mitigate bias, and better understand student comprehension within the neuroscience curriculum. These analyses can also provide insights into potential disparities within the curriculum.

The core concepts in neuroscience were developed with input from over 100 neuroscience educators through an iterative process that identified eight key concepts and accompanying explanatory paragraphs. Currently, this group is focused on unpacking the key conceptual elements within each core concept (Chen et al., 2023a). The initial unpacking of four out of the eight core concepts (Evolution, Gene-environment interactions, Plasticity, and Structure-function relationship) has been completed (Chen et al., 2023b). Interestingly, within the NCI draft tool these four concepts have demonstrated reliability, evidenced by Cronbach's alpha scores greater than 0.7. In contrast, the remaining four concepts, which are still in the process of being unpacked, exhibited lower reliability within the NCI. The difference in reliability demonstrates the importance of the unpacking process. The unpacking of the four concepts, significantly benefited the development of our assessment by providing a clear framework for formulating precise and targeted questions.

Phase 1	Phase 2	Phase 3
Incorporate qualitative data from student feedback to address gaps in understanding and create multiple choice distractor options. Collaborate with other institutions to gather data from diverse curricula. Refine NCI tool by editing questions with low discrimination indices to enhance validity & reliability.	Conduct additional rounds of testing and exploratory factor analysis in further phases of NCI tool development. Collaborate with other institutions to increase student engagement, gather data from diverse curricula, and enhance the validation process.	Finalize questions within NCI tool. Administer tool to 1000+ students across various institutions and conduct Cronbach's alpha and other analyses.
Across all three phases: Conduct gender, race, and first-generation analyses to address potential biases and create a more inclusive assessment		

Table 2. Neuroscience Core Concepts Inventory (NCI) Multi-Phase Development Plan.

The core concepts that have not yet been unpacked present a challenge in terms of assessment reliability. To formulate better questions for the remaining concepts, we need to engage in a similar unpacking process. This involves deconstruction of each concept to identify key elements and sub-concepts. As a next step, we will use the eight fully unpacked core concepts to further refine the NCI, ensuring questions are grounded in a thorough understanding of each concept. This will ultimately lead to more accurate and meaningful evaluations of student learning in the field of neuroscience.

Multi-Phase Development Plan

The NCI tool is currently in a draft phase, and we plan to move towards a multi-phase process for tool development (Table 2), modeled after the Microbiology Concept Inventory (MCI; Rennpferd et al., 2023). Our draft phase involved generating questions and administering these to students. Like the MCI, in this first phase of tool development we plan to join forces with collaborators from the neuroscience community to revise and edit our current questions. In future iterations, students will be required to provide a written rationale for each multiple-choice answer they select. The qualitative data from these rationales will be analyzed to identify misconceptions and gaps in understanding, guide question revisions, and develop plausible incorrect answer options. We will also edit or create new questions to address those with low discrimination indices enhancing validity and reliability.

In the MCI's second phase, the tool was given to a larger student group, and responses were analyzed to identify common misconceptions. Similarly, we plan to conduct additional rounds of testing and analyze student's multiple choice & open-ended responses for common misconceptions. Collaboration with other institutions will allow us to increase student engagement, gather data from diverse curricula, and enhance the validation process. The analysis from phase two will inform the third phase, where the tool's validity and discriminatory power will be further validated. Phase three will involve finalizing questions and expand testing to a larger group of students (1000+) across multiple institutions. More robust statistics, such as an exploratory factor analysis, will be conducted on this final phase of the NCI tool.

Across all phases of tool development, we plan to work with a large group of neuroscience educators and researchers to determine how many and which questions need to be revised. We will also explore gender, race/ethnicity, and generation in college analyses to address potential biases and create a more inclusive assessment. Additionally, we plan to consider primary and secondary majors as well as minors. We believe these steps aim to advance the NCI tool's effectiveness, inclusivity, and validation through iterative development and collaboration with various institutions.

Collaboration and Dissemination

Collaboration with other institutions is necessary for validating and enhancing the effectiveness of the NCI tool. Through collaboration we plan to increase the number of students engaging with the tool to gather data from a broader range of institutions with diverse neuroscience curricula. Different institutions have unique curricular requirements, teaching methods, and student populations, which can influence the performance and perception of the NCI tool. We hope to collaborate with multiple institutions to lead to a more robust validation process.

To date, we have presented this data at the Neuroscience Teaching Conference held in Winston Salem, NC and received feedback from 17 neuroscience educators representing 17 different institutions across 11 different states. All respondents (100%) expressed interest in collaborating to help edit and refine questions and/or administering multiple iterations of the tool to their students as we continue to refine. This enthusiastic response is very encouraging as we aim to engage with numerous institutions and expand our network of collaborators for NCI tool development. We also presented this research at other neuroscience conferences, such as the Society for Neuroscience, to further broaden our collaborative efforts.

This study marks the development of a draft, and we are actively seeking collaborators for the first phase of a multi-phase process for tool development. Those wishing to collaborate for tool development, please fill out this Qualtrics Form.

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