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The Development of Core Concepts for Neuroscience Higher Education: From Beginning to Summer Virtual Meeting Satellite Session

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Neuroscience curricula vary widely across higher education institutions due to the lack of an accrediting body or a set of unified educational concepts or outcomes. Each institution has developed a unique set of fundamental knowledge, topical subdisciplines, and core competencies to be delivered in a neuroscience program. Core concepts would provide neuroscience departments and programs with a generally agreed upon set of overarching principles that organize knowledge and can be applied to all sub-disciplines of the field, providing a useful framework from which to approach neuroscience education. We set out to develop a consensus set of neuroscience core concepts to aid in higher education curricular development and assessment. Suggestions for neuroscience core concepts were solicited from neuroscience faculty in a nationwide survey and analyzed using an inductive, independent coding model to identify eight core concepts based upon survey responses. Accompanying explanatory paragraphs for each core concept were developed through an iterative process. We presented the resulting core concepts to 134 neuroscience educators at a satellite session of the Faculty for Undergraduate Neuroscience 2020 Summer Virtual Meeting (SVM). Individuals and groups of faculty provided feedback regarding the accuracy, comprehensiveness, and clarity of each concept and explanatory paragraph, as well as the structure of the document as a whole. We continue to refine the core concepts based upon this feedback and will distribute the final document in a subsequent publication. Following publication of the finalized list of core concepts, we will develop tools to help educators incorporate the core concepts into their curricula.

Key words: conceptual knowledge; curriculum; assessment; neuroscience principles; STEM education; core concepts; Summer Virtual Meeting; higher education

RATIONALE FOR CORE CONCEPTS

Given the growing body of knowledge in neuroscience and the broad, integrative nature of the discipline, educators need to be selective about what knowledge to impart to students. One strategy for organizing a field of knowledge is the use of core concepts. Core concepts are defined as overarching principles that organize knowledge and can be applied to all sub-disciplines of a field, making them useful for curriculum development and assessment. Core concepts are different from fundamental facts (which state basic information), topical subdisciplines (which list topics), and core competencies (skills that prepare students to be effective practitioners). Consensus lists and inventories of core concepts have been well established in physics (Hestenes et al., 1992; Halloun et al., 1995) and physical geography (Bacon and Green, 1981). Recently, cross-cutting lists that connect knowledge have also been identified in kinesiology (Hudson, 1995), cybersecurity (Parekh et al., 2018), bioinformatics (Wilson Sayres et al., 2018), microbiology (Merkel and the ASM Task Force on Curriculum Guidelines for Undergraduate Microbiology, 2012), physiology (Michael et al., 2017), and biological life sciences (AAAS, 2011). Other fields, such as language science and psychology, have been unable to generate consensus in determining important content areas and core concepts remain contested (Howell et al., 2014; Chomsky, 2015).

Neuroscience has yet to construct a list of consensus core concepts for higher education. Although the Conceptual Elements Framework could be used to apply general biology core concepts to neuroscience discipline-specific knowledge (Cary and Branchaw, 2017), we aimed to uncover core concepts targeted to neuroscience. Previously, "core concepts" were published by the Society for Neuroscience BrainFacts.org (Society for Neuroscience, n.d.b). However, these core concepts were targeted at K-12 education, largely content-based, and aligned with the U.S. Next Generation Science Standards. Separately, the SfN's Neuroscience Training Committee developed core competencies for neuroscience undergraduates that are primarily skills-based, focusing on analytical and scientific thinking, communication, and research conduct (Society for Neuroscience, n.d.a). Conceptual knowledge of subdisciplines within neuroscience is listed as a core competency, but at a broad level that does not delineate overarching principles across the subfields. Therefore, our project targeted higher education and distinguished core concepts from fundamental facts, content, and competencies.

PROCESS FOR DEVELOPING CONSENSUS CORE CONCEPTS

In order to define consensus core concepts, we developed a strategy that allowed us to gather feedback at multiple time points from neuroscience educators with a broad array of expertise and representing a range of institution types. It was important that the process allow us sufficient ownership to define and enforce parameters for what constituted a "core concept" and to structure the comprehensive list of concepts. Our process was informed by previous work in disciplines such as physiology and microbiology (Michael and McFarland, 2011; Merkel and the ASM Task Force on Curriculum Guidelines for Undergraduate Microbiology, 2012).

We released a nation-wide survey in spring 2020 to solicit suggested neuroscience core concepts from neuroscience faculty. One hundred-nineteen neuroscience educators responded. Through analysis of the survey responses, we identified eight core concepts using an inductive, data-driven, independent coding approach. The core concepts and accompanying explanatory paragraphs were further refined in an iterative process. Each co-author independently coded all responses. We then examined the overlap of the codes and revised them into core concepts over five iterations. The first two iterations primarily focused on capturing breadth of collected data within an identified code. This was followed by three iterations that primarily focused on refining verbiage for clarity, accuracy and completeness.

We defined the following parameters for neuroscience core concepts:

• Applicable across subdisciplines of neuroscience: A core concept is a principle that transcends across subdisciplines of neuroscience. Any concept that is integral to neuroscience should be applicable to any subfield.

• Simplest statement that conveys the essential nature of the concept: Core concept statements should be concise, readable, complete, and accurate in order to maximize comprehension and minimize misinterpretation.

• Timeless: Core concepts should reflect principles that are enduring. Experimental findings may alter our knowledge base of facts in a dynamic process, such that the scientific consensus shifts on various facts. However, principles are not as liable to change, because they describe a fundamental nature or design of nervous systems. Statements of core concepts should be written to withstand new experimental discoveries.

• Applicable across all species that have a nervous system: Each core concept must be correlated to all creatures that have a nervous system.

• Broader than a fact (unpackable): Concepts connect disparate facts by organizing facts into patterns. The AAAS Vision & Change Report (2011) recommends that educators use facts to promote understanding of broader concepts. Therefore, concepts can be deconstructed or "unpacked" into smaller ideas (Michael et al., 2017), some of which may be more tightly connected to a given subdiscipline of the field.

• Not a competency: Competencies are characterized as soft and hard skills that can be taught. Core concepts, however, are overarching principles encompassing the knowledge across all sub-disciplines in a field.

The final document and a complete description of the iterative process will be provided in a subsequent publication.

The eight core concept titles identified in our preliminary draft were: communication modalities, information integration, structure/function, plasticity, emergence, genetics, evolution, and (nervous system) function.

This list of eight core concepts and their accompanying explanatory paragraphs were presented to a working group of neuroscience educators. Our original plans were to leverage the unique Faculty for Undergraduate Neuroscience (FUN) educator community in an approved breakout session for the 2020 FUN Workshop. When the COVID-19 pandemic required a Summer Virtual Meeting (SVM), we expanded the session to include Biology education researchers via Society for the Advancement of Biology Education Research (SABER) and American

Table 1.1	
Breakout round 1 survey questions	● Does the core concept statement adequately encompass a fundamental nature of neuroscience? ● Is the explanatory paragraph accurate? ● Is the explanatory paragraph comprehensive? ● Please provide any suggestions you have regarding the core concept. For example, you may want to consider phrasing, content, scope, etc.
Table 1.2	
Breakout round 2 discussion questions	● Considering the entire list of core concepts, do any concepts need to be eliminated? ● Are any core concepts missing? ● Do the core concepts complement each other and fit together well?
Table 1.3	
Post-session debrief survey questions	● For each proposed core concept, select whether it should be eliminated, modified or kept as is. ● What core concept(s) need to be added? Please explain why. In your explanation, please describe how it meets the criteria for a core concept (spans across subdisciplines of neuroscience, simplest statement to convey the essential nature of the concept, timeless, applicable across species with nervous systems, broader than a fact, and not a competency) and explain how it is distinct from the existing core concepts.

Table 1. Satellite session survey questions.

Physiological Society (APS) Teaching and Central Nervous System section members. FUN endorsed the expanded session as a satellite to the SVM. Due to the virtual nature of the working session, we were able to host an international audience that included educators from primarily undergraduate institutions, graduate institutions, Hispanic-serving institutions (HSIs), and one historically black college or university (HBCU).

Prior to attending, satellite session registrants were asked to read the list of neuroscience core concepts and complete a questionnaire in order to familiarize themselves with the core concepts document. One hundred-fourteen out of 134 registrants completed the questionnaire. We hosted 103 educators in the working satellite session to refine the core concepts for clarity, accuracy, and completeness. The three-hour satellite session included an introduction to the purpose and definition of core concepts and an explanation of our process, followed by two rounds of breakout work and large-group discussion. Because core concepts are overarching principles that cut across subdisciplines of neuroscience, we believed it was important that a range of neuroscience experts examined each core concept. As such, participants were pre-assigned to breakout rooms designed to contain a mixture of neuroscience subfield expertise.

Individuals were asked to complete a Qualtrics survey about their assigned core concept prior to the first breakout group discussion and then to discuss their ideas in the first breakout room (Table 1.1, 56 respondents). The second breakout round asked groups to discuss the core concepts list as a comprehensive document (Table 1.2). Feedback from the first and second round group discussion, as well as the large group discussion, was collected via Zoom chat and video recording. A post-session debrief survey solicited final comments from participants (Table 1.3, 27 respondents).

FEEDBACK FROM WORKSHOP PARTICIPANTS

As previously noted, we identified eight core concept categories in our analysis of the Spring 2020 national survey. For each core concept we generated a title, a short statement of the concept, and a longer explanatory paragraph. Those titles, statements, and explanatory paragraphs were provided to workshop attendees for discussion and feedback. As an example, the draft statement and explanatory paragraph for the "Plasticity" core concept is shared below to help JUNE readers understand the structure of the core concepts document and as context for the discussion of workshop feedback and our ongoing revision process that follows.

Title: Plasticity

Statement: Nervous systems adapt to experiences.

Explanatory paragraph: The nervous system is malleable. From early developmental stages and throughout life, the nervous system strengthens and weakens components in response to experience. This modulation, or plasticity, occurs in response to intrinsic and extrinsic influences, including activity, injury, disease, and usage. Nervous system plasticity is a dynamic process that allows the nervous system to flexibly meet functional needs, including homeostasis and information storage.

Workshop attendees generally received this core concept favorably, with 26 out of 27 (96.3%) of post-survey respondents supporting the inclusion of the "Plasticity" concept as is or with some modification (Figure 1). A notable suggestion from workshop attendees recommended that the explanatory paragraph be revised to broaden the scope so that it more directly addresses behavioral and cognitive aspects of plasticity.

Similar to the "Plasticity" results above, most respondents to the first Qualtrics survey (Table 1.1) also considered their assigned core concept to encompass a fundamental nature of neuroscience (89.1%; 49/55). While most respondents to this survey also indicated that the explanatory paragraph associated with their core concept was accurate (87.3%; 48/55), there was less agreement that the explanatory paragraph was exhaustive, with only a minor majority of respondents indicating that their assigned core concept explanatory paragraph was comprehensive (61.8%; 34/55).

These results are consistent with the post-session debrief survey (Table 1.3), in which greater than 88% of the 27 respondents supported keeping six concepts as is or with slight modifications, with less agreement for the "Genetics" and "Evolution" concepts (Figure 1).

Some common themes emerged in the suggestions provided by participants during both breakout discussions and the post-satellite session debrief survey. Comments indicated that some of the core concepts overlapped with

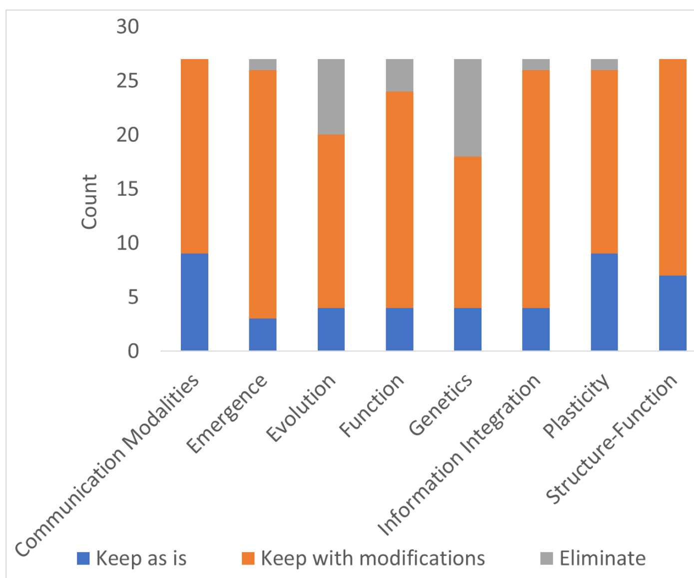

Figure 1. Post-satellite session debrief survey results. Responses from 27 participants indicate strong support for the eight draft core concepts identified by our group, with relatively weaker support for the inclusion of "evolution" and "genetics" as core concepts in neuroscience higher education. Response options were keep as is (blue), keep with modifications (orange), or eliminate (grey).

others and that terminology used in the explanatory between paragraphs was ambiguous. We noted a tension describing the core concept generally enough to encompass multiple subdisciplines in neuroscience and using enough detail for the core concept to be understandable and distinct. Other work on core concepts for biology similarly struggled with the challenge of articulating concepts that are broad enough to be applied to multiple subdisciplines without being overly detailed (Dirks and Knight, 2016). A common recommendation from workshop participants to address this tension suggested adding a preamble to define the meaning of ambiguous terms and explain the intended audience and function of the core concepts. Finally, concern was raised that some concepts were overly focused upon cellular and molecular aspects of neuroscience and insufficiently addressed behavioral, cognitive, and clinical aspects of the field.

FUTURE DIRECTIONS

We are currently revising and refining the core concepts document based on feedback received during the 2020 FUN SVM working satellite session event. We will revise core concept statements and clarify explanatory paragraphs as well as add a preamble to explain the purpose, audience, and vocabulary of the document. We will also consider whether any concepts in the preliminary list should be consolidated. After considering all feedback, we will publish the final Neuroscience Core Concepts document in a subsequent journal article.

Our goals for the next iteration of the Neuroscience Core Concepts publication are to improve the explanatory paragraphs accompanying each core concept using language understandable to neuroscience educators, without the requirement for specialized knowledge in subdisciplines of neuroscience. The list will not be intended for use directly with undergraduate students, so educators may need further resources to confidently incorporate core concepts into their curriculum. We plan to equip educators with examples of how neuroscience core concepts align with topics typically taught in higher education neuroscience courses and with strategies for explaining each core concept to students.

A consensus-driven list of core concepts will enable the development of additional tools in evidence-based teaching. We will use the list of neuroscience core concepts to define learning progressions in neuroscience higher education. A learning progression is a series of descriptions of student thinking in a science practice, concept, or idea which describe different stages of sophistication and coherence. By using learning progressions to assess and track student progress, educators can use knowledge of student learning stages to adapt curriculum choices based on where students are in their learning. An empirically tested learning progression scale can also be used as a standardized scale to assess the effectiveness of teaching strategies, helping to propel neuroscience education.

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