EDITORIAL
Unpacking and Utilizing Neuroscience Core Concepts

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Core concepts, or overarching principles that identify patterns in processes and phenomena, provide a framework for organizing facts and understanding. Core concepts have existed for many years in some life science disciplines, including biology, microbiology, and physiology, yet have only recently been published for neuroscience through a multi-year community-derived project which identified the following neuroscience core concepts: Communication Modalities, Emergence, Evolution, Gene-Environment Interactions, Information Processing, Nervous System Functions, Plasticity, and Structure-Function Relationship. The current phase of the core concepts work involves two arms: utilizing and "unpacking." Work on utilization of core concepts focuses on strategies for utilizing the core concepts in courses, curricula, and assessment, and in diverse institutional contexts. The process of unpacking involves deconstructing a core concept into its key underlying components. Prior to the 2023 FUN Workshop, we consulted faculty members with relevant experience to aid in the preliminary unpacking of four core concepts (Evolution, Gene-Environment Interactions, Plasticity, and Structure-Function Relationship). The preliminary drafts of the unpacked core concepts were shared at the Faculty for Undergraduate Neuroscience (FUN) Workshop and Neuroscience Teaching Conference (NTC) for community feedback and guidance. This editorial describes community feedback and guidance that we received from the conferences to inform future steps.

Key words: conceptual knowledge; curriculum; assessment; neuroscience principles; STEM education; core concepts; conceptual elements; unpacking; teaching tools

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Core concepts are overarching principles that identify patterns in processes and phenomena in a discipline. As such, they are broader than a fact, content item, or topic area in a field and provide frameworks for understanding facts, content, and topic areas. Neuroscience core concepts, developed using a community-derived approach, were published in 2023 (Chen et al., 2023) and presented at the 2023 FUN Workshop (Bellingham, WA), as well as at the 2023 Neuroscience Teaching Conference (NTC, Winston-Salem, NC). While the Society for Neuroscience developed core concepts for K-12 outreach in a sub-committee (Society for Neuroscience, 2018), the project by Chen et al. (2023) used an empirical approach to identify neuroscience core concepts for higher education and involved a larger portion of the neuroscience education community to determine neuroscience core concepts. Given that neuroscience draws from physics, psychology, physiology, biology, and other disciplines, core concepts for these disciplines overlap with neuroscience, but as a field and as an educational endeavor, neuroscience is unique from other disciplines and therefore benefits from its own set of core concepts.

The FUN Workshop "Re-imagining Neuroscience Education" identified four themes for abstract submissions: inclusive pedagogy and active learning approaches; student and faculty wellness and identities; integrative STEM education; and decolonizing neuroscience. "Utilization and Unpacking Neuroscience Core Concepts" was accepted as a mini-symposium under the inclusive pedagogy and integrative STEM education themes. The presentation at the 2023 FUN Workshop briefly introduced the published core concepts and emphasized the next phases of our ongoing work: unpacking the core concepts and resource development for faculty interested in utilizing them in their own work.

The previous phases of this project used an inductive, data-driven coding approach to identify recurrent themes from a survey of neuroscience educators, distributed internationally in Winter and Spring 2020. The draft concepts were provided to the FUN community and others in a three-hour satellite workshop to the 2020 FUN Summer Virtual Meeting. At the 2020 workshop, attendees were asked to provide feedback on the draft concepts, including suggestions for revisions or different concepts (see Chen et al., 2022 for further detail of the survey and workshop process). The resulting core concepts (Chen et al., 2023) provide educators with a pedagogical tool for framing big ideas in neuroscience to aid in knowledge acquisition and transfer. Please see 'Cautions regarding core concepts' section below for discussion of the limits of core concepts.

Benefits of Using Core Concepts

As overarching principles that identify patterns in processes and phenomena, core concepts provide a framework for organizing facts and understanding. Using core concepts provides multiple benefits for students. Core concepts focus on deep learning and help learners build conceptual frameworks (vs. collections of isolated facts) in the face of exponential growth of disciplinary facts and knowledge (Michael et al., 2017; White et al., 2021; Danos et al., 2022). Since core concepts are applicable across subdisciplines of the field, they can be utilized to cross disciplinary boundaries in integrative STEM education efforts. Core concepts encourage students to integrate knowledge from different (sub)disciplines and enhance transfer of learning to new contexts (Michael, 2022; Doherty et al., 2023). For example, a student may learn about voltage-gated ion channel protein structure and, separately, learn about neural circuit motifs or diffusion tensor images of white matter pathways. Tying the distinct topics to the structure-function relationship core concept statement, “Structure permits and constrains nervous system function, and function shapes structure,” can help students examine the larger patterns in their understanding and thereby make predictions about how structural alterations would alter ion channel, circuit, or network function. One characteristic of inclusive teaching is explicit attention to student transfer of learning. Core concepts are an important tool for enhancing student transfer of learning in that they provide students with a set of big ideas that help them to identify common understanding and to generalize as they build mental frameworks that unite new with existing understanding. Additionally, core concepts afford time and space to bring big ideas to life, which is especially positive for students from non-traditional backgrounds (Danos et al., 2022). Finally, core concepts address common learner misconceptions about important disciplinary concepts (Hestenes et al., 1992; National Research Council, 1997).

Core concepts also benefit faculty as a pedagogical and assessment tool. Core concepts can provide a basis for assessment (Couch et al., 2017) and gathering data that may prompt new teaching approaches. Faculty can use core concepts to track student growth and understanding as they progress through a course or program. The use of core concepts can help faculty be more inclusive in their teaching by providing a transparent teaching and learning framework for students to scaffold new knowledge (CAST, 2018; White et al., 2021; Danos et al., 2022). Core concepts can also be informative for course and curriculum design, without prescribing the design.

Cautions Regarding Core Concepts

Importantly, the core concepts are not a list that dictates course or curricular content. They do not determine which content should be taught in specific courses or programs. Different programs will continue to offer unique coursework depending upon the needs of their students and upon faculty assets. The core concepts do not redefine the field of neuroscience or neuroscience education, nor do they define subdisciplines or boundaries of the field. For example, the core concepts do not draw epistemic boundaries to determine whether or how neuroart therapy should be considered part of the field of neuroscience. The core concepts do provide tools that help students transfer ideas across diverse coursework and prepare students for diverse and interdisciplinary careers, including neuroart therapy.

Core concepts do not address competencies or skill development, which should also be integrated into courses and curricula. As described by Danos et al. (2022), core concepts differ from grand challenges of systemic racism, androcentrism, homophobia, genocide, and slavery in the history of STEM. Danos et al. (2022), while differentiating between core concepts vs. grand challenges, called out a need for students to be explicitly taught about how the field of comparative vertebrate anatomy has impacted people, to the benefit of some and to the harm or marginalization of others. They called for educators to create an environment for students to feel valued throughout their courses and institutions, as well as to help students self-identify as a member of their field. We second this call for our field of neuroscience education. The vital topics of diversity, inclusivity, and decolonization were a focus of the 2023 FUN Workshop and are a fundamental goal for the neuroscience community to effectively implement into our courses and curriculum, in addition to core concepts and core competencies.

Current Stage of Core Concepts in Neuroscience

The presentations at FUN and NTC introduced two arms of the current phase of core concepts work: utilization of core concepts and unpacking of core concepts. Work on utilization of core concepts focuses on strategies for implementing the core concepts in courses, curricula, and assessment, and in diverse institutional contexts. See ‘future directions’ below for further discussion of this arm of the work.

In order to aid instructor use of core concepts, it is beneficial to deconstruct a core concept into its key underlying components. Education researchers have called this process “unpacking” (Michael et al., 2017), or identification of the conceptual elements (Cary and Branchaw, 2017). The unpacking process is useful because creating a hierarchy of underlying conceptual elements helps to explain and define the overarching core concept, enables students to avoid common conceptual difficulties, and provides an opportunity to explicitly address common misconceptions (Hiatt et al., 2013). As a result, we can develop and convey clearer learning outcomes to students (Michael et al., 2017). Students then have a more detailed conceptual framework to scaffold their understanding of the components and processes that comprise a core concept (National Research Council, 2000).

Prior to the FUN and NTC workshops, we selected four core concepts for preliminary unpacking (Evolution, Gene-Environment Interactions, Plasticity, and Structure-Function Relationship). To generate drafts as a basis for conversation at the meetings, we surveyed and interviewed faculty with relevant experience in one of these core concepts. For each, we invited neuroscientists whose research focus and/or neuroscience teaching experience aligned with a core concept to complete an interview or survey regarding how they would unpack the concept into subconcepts for higher education. When extending invitations, we made a particular effort to include individuals from a breadth of neuroscience subdisciplines and were able to interview or survey 2-8 faculty per core concept. We then integrated the ideas generated from these discussions to generate a preliminary draft for each core concept. The preliminary drafts of unpacked core concepts were presented at FUN and NTC summer 2023 workshops for community feedback and guidance. We do not provide the drafts here because they are not yet vetted by the wider neuroscience education community and, therefore, should not be in broad circulation. The example provided in Table 4, however, from Chen et al., (2023) is similar in nature to the draft unpackings. While this process has provided a starting point for the unpacking process, the main phase will come in the form of surveys released to the broader neuroscience education community to provide comprehensive feedback for final unpackings.

FEEDBACK FROM FUN AND NTC

During the FUN mini-symposium and NTC session, the in-person discussion and written feedback fell into three areas: using the core concepts, unpacking the core concepts, and general questions. At the FUN session, 50 minutes were spent on background information about core concepts, 25-30 minutes on utilization of core concepts, and 10-12 minutes to brainstorm revisions to the draft unpacking. This differed from the NTC presentation which spent more time on unpacking but did not have sufficient time for participants to brainstorm possible uses of core concepts in assignments, assessment and programs. Approximate attendance at the FUN and NTC sessions were 35-40 and 60-65, respectively, for a total of approximately 100 individuals. The discussion and written and verbal feedback from both sessions are summarized below.

Feedback on How to Utilize Core Concepts

Attendees self-selected into small groups focused on utilizing neuroscience core concepts in teaching activities, course revision or design, program/curriculum mapping, or assessment, and shared ideas within their assigned area of focus through Google Docs.

Discussions about teaching activities acknowledged that core concepts are already interwoven in existing curriculum and need to be made more explicit by instructors. For example, instructors can list core concepts on the syllabus and identify them as they surface throughout the course content. These light-touch practices help with generalization and metacognition (Hogan and Rabinowitz, 2009; Moro et al., 2023). Attendees also noted that courses need not address each neuroscience core concept, but it is likely that a program teaches the comprehensive list of core concepts as they progress through the curriculum. Attendees also suggested concrete teaching activities. For example, in the first class meeting, students can classify subfield-specific concepts or content into the core concepts. In a later class meeting, students can do the same task again and observe how their classifications changed. Card sorting tasks (Smith et al., 2013; Bissonnette et al., 2017) are evidence-based teaching tools to measure conceptual expertise, and workshop attendees recommended use of card sort activities to teach neuroscience core concepts. Groups also brainstormed case studies which can be used to teach neuroscience core concepts. For example, a case study on autism can be taught as a disruption of a Communication Modality, the result of Information Processing, or a product of Gene-Environment Interactions, to teach any, or multiple, of these core concepts.

A number of discussions arose regarding how core concepts should be used relative to other curricular goals. For example, some attendees wondered if core concepts should supersede competencies (or vice versa). We were able to explain that neither concepts nor competencies supplant the other. Best practices for course and curricular design suggest that competencies, content, and concepts should be parallel components, with the relative importance of each depending on course goals and context. A group of attendees suggested explicitly situating the core concepts within a larger framework that includes competencies/skills and affective learning to better explain the relationship between core concepts and competencies.

Some attendees noted that their program learning objectives list conceptual knowledge as a single item, so the neuroscience core concepts offer a way to sub-list particular conceptual knowledge under the general umbrella of conceptual knowledge. Core concepts do not prescribe specific content (as stated above), nor do they address core competencies such as ethics and communication (for reference see competencies developed by SfN's Neuroscience Training Committee https://www.sfn.org/careers/higher-education-and-training/core-competencies). Therefore, core concepts provide an instructional and design tool but do not replace content and competencies in course and curriculum development/revision. Additional discussions about curriculum mapping suggested that neuroscience core concepts can be used post-hoc for program-level assessment and program review. Assessments of neuroscience core concepts can identify an individual program's gaps or deficits, or identify a unique identity or strength. Some participants voiced interest in other programs piloting an assessment, and some participants voiced interest in developing a validated assessment that is usable and accurate.

A question was raised regarding how to implement neuroscience core concepts in interdisciplinary courses/curricula for which other disciplines' core concepts may also be relevant (i.e., physics, psychology, physiology, etc.). Attendees also noted as a challenge that students receive some of their neuroscience training outside of courses taught by neuroscience faculty. Core concepts from other disciplines may be important to deploy alongside neuroscience core concepts depending on the course/curriculum, student training needs and career goals, and instructor goals. Instructors or programs will need to consider the appropriate balance for their own contexts.

Additional conversation centered on more specific details of assessment structure/questions, specific assignment ideas, and possible models for implementing core concepts in program/curriculum design.

Feedback on Preliminary Unpacking of Core Concepts

As attendees reviewed the preliminary unpacking of the Evolution, Gene-Environment Interactions, Plasticity, and Structure-Function Relationship core concepts, they suggested wording changes that clarify when a conceptual element can be applied to all situations or in only a subset of situations. Attendees also noticed some redundancy and overlap between conceptual elements, either within a core concept or between two core concepts. Psychologists and cognitive neuroscientists in the audience noted that they would emphasize the environmental component within the Gene-Environment Interactions core concept and suggested elimination of some conceptual elements which focused too heavily on genes. Conceptual elements and sub-elements seen as not essential were identified for removal from the Gene-Environment Interactions core concept. In contrast, attendees asked for addition of conceptual elements to the Structure-Function Relationship to break the core concept into more feasible components. Attendees also questioned whether the order and numbering of conceptual elements was significant. Again, we do not provide the draft unpackings nor revisions at this time as they await review and modification by the broader neuroscience community, which will occur through survey (see Future Directions, below). Given that these unpackings will be revised, we feel that providing drafts in this publication would unnecessarily complicate the work we are trying to accomplish or could result in inappropriate adoption of the draft versions. As addressed below, the final unpackings will be published after the revised drafts are reviewed by the neuroscience education community.

General Feedback, Questions and Advice

A question was posed about the degree to which the past process for developing neuroscience core concepts and the final concepts document were inclusive and anti-racist. While no endeavor is free from bias, we made significant efforts to ensure our process was inclusive of diverse neuroscience educators. Detailed explanations of the process can be found in Chen et al. (2022) and Chen et al. (2023), with the latter also containing the final concepts document. We believe it is important that the work reflects the input provided by the community rather than the opinions or ideas of the authors. A large-scale recruitment effort was used to invite neuroscience educators into the process of suggesting core concepts through social media, through FUN, American Physiology Society (APS) nervous system and teaching sections, and Society for the Advancement of Biology Education Research (SABER) listservs, and through word of mouth. Nevertheless, limitations in who responded to survey and workshop invitations throughout the process, along with individuals' cultural backgrounds, training, and implicit biases, could influence the suggestions and feedback that shaped the final concepts document. Participant demographics are provided in Chen et al. (2023). When developing anti-racist and inclusive instruction, we believe it is critical to emphasize that competencies such as ethics (including student development in inclusive and anti-racist science) should be embedded throughout neuroscience coursework and curriculum. Both the nature of this area as a skill and its high degree of importance suggest that it could be interwoven into discussions of all concepts rather than defined as a single stand-alone concept. The specifics of how this might be accomplished will vary by course and program. For example, a particular course may teach the topic of pain sensation and perception, and may tie it to the structure-function relationship, emergence, or plasticity concept(s), depending on the goals of the course. Regardless of which core concept(s) is/are used as a framework for the topic of pain sensation and perception, the well-documented history of medical racism in pain treatment should be an important component of the discussion (Hoffman et al., 2016).

A concern was raised regarding the degree to which the neuroscience core concepts reflect biological versus psychological underpinnings and, therefore, how relevant the core concepts are for courses and curricula in each field. In particular, is psychology sufficiently reflected in the set of concepts or individual concepts? Using the Gene-Environment Interactions statement as an example ("Unique patterns of gene expression underlie the organization and function of a nervous system and are altered by environmental factors"), the reference to genes and gene expression clearly represent a biological perspective. Nevertheless, psychology generates a great deal of information and research regarding the environment (nurture) and gene (nature) interactions that shape behavior and cognition. Again, it was important throughout the work that the core concepts document reflect the input of the community rather than the authors' opinions. Therefore, the resultant document reflects the feedback of participants. It may be that additional psychological concepts were not regularly suggested by respondents given the requirement throughout the work that core concepts apply to all nervous systems (rather than only mammalian or human nervous systems). It is of note that we examined whether respondents in the pre-working session survey differently valued the core concepts based on respondents' area of expertise in neuroscience. Possible areas of expertise included behavioral, cognitive, developmental, systems, computational, clinical, cellular and molecular, neuroscience education research, other, or any combination. There were no instances in which a given concept was supported or not supported based on respondents' areas of expertise (see Chen et al. 2023).

Given that our goal is for neuroscience faculty from biology and psychology, as well as other areas of neuroscience, to find the core concepts applicable to their areas and courses, we take this concern seriously. To address this concern, we will pay particular consideration during the unpacking to ensure that psychological, and other non-biological, perspectives and principles are explicitly incorporated.

FUTURE DIRECTIONS

While the neuroscience core concept statements and explanatory paragraphs have been vetted by over 100 neuroscience educators (Chen et al., 2023), the unpacked conceptual elements and sub-elements still need extensive community input and revision. This iterative process to unpack the core concepts will ensure that articulated conceptual elements identify the essential elements for undergraduate education, the suggestions from the FUN and NTC meetings are incorporated, and that the neuroscience core concepts are useful and culturally-relevant to the neuroscience education community. Future steps in the unpacking process will include a Qualtrics survey widely distributed to the broader neuroscience educator community to assess whether each concept's unpacking is complete and accurate. If needed, focus groups will be recruited to provide additional input for further iterations. We invite interested/affected groups and non-academic partners (Reed and Rudman, 2023) to join the unpacking process. Finalized unpackings of core concepts will be published individually as they are validated.

The second arm of the current work–utilization of core concepts–will provide examples and tools for implementation of core concepts into courses, curricula, and assessment. This arm, like the unpacking work, will be most productive with the input of educators from diverse institutional contexts and perspectives. We invite members of our FUN community and others to propose models of how the identified neuroscience core concepts can be effectively embedded to counter common misconceptions, provide tools for teaching neuroscience core concepts, suggest scaffolding methods when teaching neuroscience core concepts in introductory versus advanced courses, develop assessment tools based on neuroscience core concepts, test whether use of neuroscience core concepts improve student learning processes such as metacognition or critical reasoning, and collect empirical data on the use of neuroscience core concepts to introduce new subfields of neuroscience to trainees.

There is clearly a lot of work to be done. Please join us in developing tools that enrich neuroscience education by participating in the unpacking process and/or by developing and reporting teaching tools, curricular innovations, and assessment tools that implement the core concepts.

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