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Physiology core concepts in the classroom: reflections from faculty

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Crosswhite PL, Anderson LC. Physiology core concepts in the classroom: reflections from faculty. Adv Physiol Educ 44: 640–645, 2020; doi:10.1152/advan.00183.2019.—It is increasingly difficult for faculty to cover all of the content in a physiology course. Given this constraint, recent efforts in the physiology teaching community, and in particular the Physiology Majors Interest Group (P-MIG), have promoted using core concepts to help students master key physiological principles. This report summarizes the experiences of four faculty members who teach physiology using the core concepts in various educational environments and identifies several common strengths and challenges they have encountered thus far. Strengths of using the core concepts include the transfer of knowledge to solve unknown problems and providing a framework to build a course. Challenges include applying them in a teach-taught course and balancing time spent on content and the core concepts. This is the first report to document the use of the physiology core concepts in a course, and the authors encourage additional faculty to not only adopt the core concepts for their own use, but share their approaches and experiences with the entire teaching community.

INTRODUCTION

The core concepts of physiology grew from the changing landscape of undergraduate physiology education. Because of the expansion of knowledge in the field of physiology, teachers cannot cover in depth all of the content in any given course. For example, the Human Anatomy and Physiology Society’s (HAPS) most recent list of learning outcomes for students taking a two-semester human anatomy and physiology course includes ~840 different outcomes (https://www.hapsweb.org/page/Learning_Outcomes). Furthermore, the integrative and conceptual nature of physiology has always been a challenging discipline for students to understand. Similar to other life scientists, as discussed by Woodin et al. (19), physiologists are turning to concepts that can be applied across the discipline to help students learn physiology (5, 7, 9, 10). In an age in which facts can be quickly produced from an online search, undergraduate students must understand concepts of physiology, particularly as they pursue careers in health care, biomedical research, and biotechnology.

While efforts to improve undergraduate physiology education have been underway for many years, the 2017 publication by Michael et al. of The Core Concepts of Physiology: A New Paradigm for Teaching Physiology (11) has generated significant interest in utilizing a concepts-based approach to teach physiology. The authors’ book is the culmination of extensive effort to engage the entire physiology teaching community, which is a monumental task given that physiology educators are divided across several professional organizations [American Physiological Society (APS), Human Anatomy and Physiology Society (HAPS), and the Society for the Advancement of Biology Education Research (SABER), for example] and siloed by institution type. In addition to the book, Michael and colleagues have also published conceptual frameworks for three individual core concepts: homeostasis, cell-cell communication, and cell membrane (4, 6, 8).

Despite increased awareness of the core concepts and the three published conceptual frameworks, significant challenges remain before the core concepts are consistently and easily used in physiology courses. One challenge is that “core” physiology courses are delivered in a variety of different formats compared with core biology, physics, or chemistry courses (15, 17). Core physiology courses are offered in many forms (physiology lecture only, lecture and laboratory, anatomy and physiology lecture and laboratory), thus resulting in diversity in course content, objectives, assessment, and teaching style. Furthermore, an instructor or department deciding to incorporate core concepts into a class would find access to validated tools and resources to be extremely lacking.

This reflective report summarizes the personal experiences from four faculty members who have been using the core concepts in a physiology course for a minimum of 2 yr. The specific purpose of this report was to identify similar strengths and challenges of using the core concepts in a course and to encourage other faculty to consider adopting them for their own use. In addition, this preliminary report can help to guide additional research examining the efficacy of using core concepts in physiology courses. It is the hope of the authors, and the P-MIG community, that, as more faculty adopt the core concepts for their use in their classrooms, the development and testing of validated tools and resources will increase and ultimately improve our students’ understanding of physiology.

METHODS

Research Design and Subject Recruitment

Four different faculty members teaching physiology to undergraduates using a core-concepts approach answered a series of questions, either verbally or in writing. Faculty were contacted directly by e-mail to determine their interest in contributing to the study. One faculty member was interviewed over the telephone, and one was interviewed using the Zoom web-conferencing software platform. Audio was recorded for both interviews. The third and fourth faculty provided written responses and are also authors of this report. All questions
Table 1. A list of questions asked during each faculty interview

1. What is the name of your institution and department?
2. How were you first made aware of the core concepts?
3. How long have you been including the core concepts in your classes?
4. What is the title of the course? Briefly describe the course and its structure.
5. How do you incorporate the core concepts in the course?
   • Are they just verbally mentioned or incorporated?
   • Are their visual or verbal cues for student to recognize the core concept?
   • Do you incorporate tools or other resources? If so, please describe.
6. Do you assess the students’ knowledge or comprehension of the core concepts? If so, please describe your strategies for assessment.
7. What are the benefits of including the core concepts into your course?
8. Have you encountered any challenges to using the core concepts?
9. What types of resources or tools would make using the core concepts easier, for you or your students?
10. Is there anything else you would like to comment on as they relate to the core concepts?

Included in the interview are shown in Table 1. Follow-up e-mails were sent to two faculty when additional clarity of responses was necessary. This small sample includes both female and male instructors who teach at different types of institutions, namely a community college, a baccalaureate college, and a large university with medical and doctoral programs. Departments and institutions were excluded, and each faculty member is identified using a pseudonym. This study was approved by the Institutional Review Board at Gonzaga University, and informed consent was obtained from all participants before interviews were conducted.

Participants and Educational Context

Participant 1: Jane (doctoral university, R1). Jane teaches physiology in a biology program at a doctoral granting university with very high research activity. She first became aware of the physiology core concepts from a colleague in her department. She was motivated to read the core concepts papers (7, 9) and has been using the core concepts from a colleague in her department. She was inspired to develop active learning exercises to use during class. In terms of assessment, the instructor incorporates several core-concept-based questions into his exams in a manner similar to how students are exposed to them during class discussion.

Participant 2: Mark (baccalaureate college). Mark teaches at a private, liberal arts baccalaureate college, in a physiology program. He attended a P-MIG information session at the 2016 Experimental Biology meeting, where he first learned about the physiology core concepts and was inspired to read up on core concept-based publications (5, 7, 10). Mark began using the core concepts in his classroom in the fall semester of 2017 and continues to use them today. The primary course in which he uses the core concepts is an introductory 200-level human anatomy and physiology course with a laboratory. He incorporates the core concepts primarily in the lecture, which focuses on physiology, whereas the laboratory is mostly anatomy. His average class size is 30–40 students.

Students are introduced to the core concepts on the very first day of class. They are tasked with watching a video lecture (previously recorded by the instructor). The core concepts lecture is available to the students all semester long. Throughout daily lectures, the core concepts are verbally emphasized or discussed, but there are no visual cues or materials built into lecture. Instead, one or two times a week, the instructor guides students through worksheets that emphasize one to three core concepts that apply to recent material covered in class.

Students work collaboratively in small groups to discuss their thoughts, and the instructor facilitates a class-wide discussion. The worksheets are not graded for completion or correct responses, but the students are provided with a key after they have completed the worksheet together. In terms of assessment, the instructor incorporates several free-response questions on all exams, including the final. The questions are similar to the type of questions incorporated into the worksheets and represent 5–10% of the students’ total score.

Participant 3: Frank (community college). Frank teaches human anatomy and human physiology courses in a biology department at a community college. Frank first learned about the core concepts in 2014 through a colleague at a different regional institution. Since that time, he has started to incorporate them into his course a little more each year. The class in which he integrates core concepts the most is a human physiology lecture course with ~40 students. The course includes a laboratory, but the core concepts are mostly emphasized in lecture.

Several core concepts are introduced to students at the beginning of the course, but they are not built specifically into course objectives or learning outcomes. Frank is one of several faculty members who teaches the course, and that continuity between sections needs to be maintained with regard to course objectives. At the same time, Frank has flexibility to deliver the content in his own manner. The current textbook used in this course [Human Anatomy & Physiology (2nd ed.) by E. C. Amerman] incorporates logos to help students visually identify four physiology “core principles” (structure-function, gradients, feedback loops, and cell-cell communication) throughout the material. Frank uses these cues to ask the students core-concept-based questions and to promote class discussion as they relate to the day-to-day course content. In terms of assessment, Frank incorporates core-concept-based questions into his exams in a manner similar to how students are exposed to them during class discussion.

Participant 4: Emily (doctoral university, R1). Emily teaches human physiology and clinical physiology to physiology major undergraduates at a large doctoral granting university with very high research activity. She was introduced to the physiology core concepts through participation in the inaugural P-MIG conference in 2017 and was inspired to develop active learning exercises to use during class and laboratory sessions on cell theory, chemistry, homeostasis, and integration. She uses these exercises weekly for in-class group work in her clinical physiology course, which enrolls 30–40 students per semester.
Frank also touched on how the core concepts help him to get students to appreciate that they may not have to “learn” as many facts about physiology as they believe.

It’s a way of teaching students how to develop real expertise, that we the current experts’ value and possess, as opposed to teaching science as just a huge bucket of facts to be absorbed and remembered. I think a lot of our students think that science is just about accumulating all the facts you can stuff into your brain. What a lot of us [faculty] find interesting about science, and want to instill in our students, is detecting the larger pattern that explains many of the facts simultaneously.

Mark also touted the benefits of the core concepts to promote the transference of knowledge using flow-down gradients and the respiratory and cardiovascular system as an example:

I love that when I cover the movement of gases in the respiratory system that I can use the core concept of flow down gradients, and the flow of blood in the cardiovascular system that the students learned previously, as an example. I tell them, you already know how this works, you just have to apply that knowledge to the movement of oxygen and carbon dioxide across a given barrier. They can pick up on the details for how gases diffuse that much faster because they know that concept.

Data Analysis

A thematic analysis approach was used for the narrative data gathered from the interviews that involved separating the analysis procedures into five distinct phases to yield meaningful and useful results. The phases included reviewing the audio recordings and notes, searching for similar themes, reviewing any themes found, defining and explaining the themes, and producing the report. The thematic analysis approach employed by the author was adapted from Nowell et al. (13).

RESULTS

Thematic analysis of the interviews revealed a number of similar themes that faculty experienced when incorporating the core concepts into their courses. The themes were divided into strengths and challenges and are summarized in Table 2. All quotations presented are reproduced verbatim from the audio recordings; bracketed words within quotations were added by the authors to provide clarity.

Strengths to Using the Core Concepts

Transfer of knowledge. Faculty repeatedly highlighted the desire for their students to solve novel physiological mechanisms or problems based on knowledge they had acquired previously. Of the four faculty members interviewed, three mentioned they believe the core concepts can help students with the transference of knowledge between physiological phenomena or mechanisms.

Jane, in particular, believes this is one of the best strengths of using the core concepts in both her plant and animal physiology courses. She highlights how the core concepts allow her to teach one physiology topic and have the students predict what will happen in mechanisms unknown to the students. She also likes how she can use them across multiple physiology courses. According to Jane:

You can make hypotheses and predictions about what will happen, and you don’t have to know all the details. The concepts apply to both plants and animals. Plants move ions the same way animals do, by creating gradients and resistance.

Frank also touched on how the core concepts help him to get students to appreciate that they may not have to “learn” as many facts about physiology as they believe.

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Providing a framework for a course. The other major strength that emerged was how faculty believe the core concepts are useful for course design and delivery of content. The core concepts provide a central framework around which to build a class and can help faculty emphasize the key material, learning objectives, skills, and other knowledge that they want students to achieve in their course.

After learning about the core concepts at a recent conference, Emily took the initiative to redesign one of her physiology courses around the core concepts. Below is an excerpt from how the core concepts were a useful tool in the context of making changes to a course that already exists:

In my experience, using the core concepts has been essential to making sure my course is aligned. For example, if I want my students to understand the core concept of homeostasis, I write

Table 2. A summary of the participating faculty and the strengths and challenges to using the Core Concepts of Physiology in a course

| Faculty | Institution Type | Course Description | Course Size, no. students | Core Concepts Used | Strengths Identified | Challenges Identified |
|---------|------------------|--------------------|---------------------------|--------------------|----------------------|-----------------------|
| Jane    | Doctoral university-R1 | Introductory Biology | 100–600 | Flow-down gradients, Mass balance | Encourages transference of knowledge | Balance core concepts with content |
|         |                  |                    |                           |                    | Provides a framework for a course | Concepts can’t be used to teach everything |
|         |                  |                    |                           |                    | Promotes active learning | Presents a challenge with team-taught courses |
|         |                  |                    |                           |                    | Encourages transference of knowledge | Balance core concepts with content |
|         |                  |                    |                           |                    | Few resources are available | Few resources are available |
|         |                  |                    |                           |                    | Presents a challenge | Presents a challenge with team-taught courses |
| Frank   | Baccalaureate college | Human Physiology | 30–40 | Flow-down gradients, Cell-cell communication | Encourages transference of knowledge | |
|         |                  |                    |                           |                    | Homeostasis | |
|         |                  |                    |                           |                    | Cell membrane | |
|         |                  |                    |                           |                    | Structure-function | |
|         |                  |                    |                           |                    | Flow-down gradients | |
|         |                  |                    |                           |                    | Cell-cell communication | |
|         |                  |                    |                           |                    | Homeostasis | |
|         |                  |                    |                           |                    | Structure-function | |
|         |                  |                    |                           |                    | Chemistry/physics | |
|         |                  |                    |                           |                    | Cell theory | |
|         |                  |                    |                           |                    | Homeostasis | |
|         |                  |                    |                           |                    | Integration | |
| Emily   | Doctoral university-R1 | Clinical Physiology | 30–40 | Flow-down gradients, Mass balance | Encourages transference of knowledge | |
|         |                  |                    |                           |                    | Homeostasis | |
|         |                  |                    |                           |                    | Integration | |
|         |                  |                    |                           |                    | Provides a framework for a course | |
|         |                  |                    |                           |                    | Promotes active learning | |
|         |                  |                    |                           |                    | | |

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learning objectives on homeostasis, have the students discuss homeostasis through a critical thinking exercise and then test the concept on an exam. As the course progresses, I continue to ask the class to think about homeostasis in each system. How is vasculature contributing to blood pressure homeostasis and temperature homeostasis? So not only is my class more aligned, the students are much more active in their learning.

Jane also mentioned the framework aspect in her interview. She likes them in particular because they help her visualize how the various topics, content, and material presented in her class are connected:

It’s a way to hang [present] things, that seem really disparate to them [the students] in one constant way.

There were other strengths to using the core concepts in a physiology class but were mentioned less often than the transfer of knowledge and providing a framework for a course (Table 2). For example, both Frank and Mark believe they allow faculty to provide an opportunity to incorporate more active learning activities for students.

Challenges to Using the Core Concepts

Team-taught courses require faculty cooperation. Frank, Mark, and Emily all mentioned how it can be difficult to implement the core concepts into a physiology course that is either delivered by a team of faculty, or where multiple sections of the same course are taught by different faculty.

Mark teaches physiology in a department where multiple instructors teach an entire semester-long section of the same course. And the department aims to provide a similar experience for all of their students, no matter from which instructor the students are learning. He found that, by using the core concepts into his class, he often struggled to keep it in alignment and on pace with the other sections.

I found that by devoting a little time every day in class, or several times a week, I very quickly could “fall behind” compared to the other faculty in my department. Our course covers a lot of physiology, even in one semester, and it’s important to our department that students are exposed to certain systems and physiological mechanisms, before they move on to the second semester or advanced physiology electives.

Similarly, Frank mentions that faculty often feel obligated to teach everything about physiology in an undergraduate anatomy and physiology course. He mentions in particular that many faculty are resistant to making significant changes to their approach to teaching physiology. For example:

The fact that, in A&P in particular, I think there are a lot of people and institutions still pretty wedded to the idea that we have to cover the entire body, we have to do it all, and so there is a lot of resistance to change.

Emily teaches physiology in a team-taught scenario, where different faculty teach different components of a single course, and she brought up the topic that this has been one of the challenges to using the core concepts. Emily stated that:

In a team-taught core, not everyone values the core concepts, not everyone sees them the same way. In one of our human physiology courses, another faculty member teaches cell physiology. I asked them to think about incorporating cell theory. They said, “I am talking about cells, that means I am automatically addressing cell theory.” We disagree on this. In another physiology course in our department, I wanted homeostasis to be a thread that ran through all topics in that course...but what ends up happening is that faculty say the word but the core concept is not there. I’m really passionate about this and sometimes feel like I’m the only one.

Balance the core concepts with physiology content. Faculty also discussed how it can be challenging to strike the right balance with how much content is delivered and how much emphasis is placed on the core concepts themselves. They also mentioned that faculty will likely need to choose which core concepts to include and which they should exclude, provided that it is unlikely any one course would effectively incorporate all 15 concepts.

Jane talked about how she and her colleagues made the decision to focus on just a few core concepts and build a course around them, as opposed to building a course around as many concepts as possible. In her words:

There are a lot of them, if you are going to go with all of them you can’t make them all part of your intro [physiology] course. I think if you’re going to have a reasoning framework for students you can’t do eight [concepts].

Mark highlighted how he made the mistake of trying to incorporate all the concepts into his physiology course the first year he used them:

I realized that by trying to teach as many core concepts to the students as I could, that I wasn’t really developing their understanding of the concepts themselves. Rather, I was just getting the students to recognize “when” a core concept applied to a topic and less so the “how” it applies. It also cost me a lot of time in class, and I always felt like I was behind in my course schedule. The next time I taught the same course I focused on the concepts that appear most in my class, and it was a much better experience for the students and myself.

Other challenges to using the core concepts were mentioned by the participants but were not discussed in detail (Table 2). Frank and Mark both mentioned the lack of publicly accessible tools for using the core concepts in a course and the difficulty in assessing a student’s ability to move beyond just recognizing when a concept applies instead of whether they understand the concept itself.

DISCUSSION

The present report highlights the experiences from four faculty members who have adopted the core concepts into a physiology course. As anticipated, the environment in which they teach physiology and their strategies for adopting the core concepts vary, yet similar strengths and challenges are revealed by their collective experience (Table 2). To the authors’ knowledge, this is the first peer-reviewed report to document the approaches used to incorporate the core concepts into a course, as established by Michael and colleagues (11).

The faculty in this sample report that use of core concepts to organize delivery of physiology content provides a flexible scaffold for students to transition from a studied system to a new system they have yet to experience; in other words, use of core concepts encourages the transference of knowledge. One of the original intentions to publishing the core concepts of physiology was to “selectively reduce the body of knowledge” that physiology students are now being asked to learn” (11). This is partly due to the rapidly increasing number of science
This lack of available tools and time commitment has not hindered three of the four faculty interviewed in this report from developing their own core concept resources, however. Given the current lack of published data on the core concepts, other avenues exist for sharing core concept materials. Faculty may consider sharing their ideas, resources, and materials on online community databases and websites for life science educators (https://www.lifescitrc.org, for example) to promote their development.

Two faculty members (Mark and Frank) mentioned that, while students recognize the core concepts, they may still have difficulty applying them to novel situations or showing the depth of understanding expected by the instructor. However, it is evident from the efforts of Jane that faculty are aware of the need for students to move beyond the recognition of a concept and toward the application. Jane has developed a variety of resources, including reasoning tools, quizzes, and practice problems, to promote students’ understanding of a concept. Jane also assesses the students’ understanding of a concept on exams.

It is likely that, before the core concepts can be widely adopted for use in undergraduate physiology education, data on their effectiveness as a learning resource or tool must be validated by the teaching community. It is the authors’ belief that validation of the core concepts as an effective means for students to understand physiology would promote their adoption and reduce any barriers to adopting them in individual courses (team-taught or otherwise) or across curricula.

Finally, it should be noted that all four faculty members were introduced to the core concepts through a department colleague or by attending a P-MIG conference. While the development of the core concepts themselves, and the resulting publications, represent a monumental undertaking by Michael, McFarland, Model, Wright, and others (4, 6–8, 11, 12), faculty would be more likely to adopt them in their courses with encouragement from a departmental or professional colleague. This again speaks to the need for the physiology teaching community to share their core concept teaching experiences via peer-reviewed publications or presentations at scientific or pedagogy-focused meetings.

In summary, this report is the first to highlight that physiology educators have started to adopt the core concepts for use in their courses, despite the lack of validation of their effectiveness or widespread availability of tools or resources. While this report focuses on efforts for using the core concepts in an individual course, other recent reports highlight the history and development of the core concepts (3) and how they might be adopted at the programmatic level (14, 18). As the field of physiology continues to rapidly expand in depth and breadth, the decision of what content to include in an undergraduate physiology course will become increasingly challenging for instructors to organize in a way that students can understand. New, future studies examining the various methods for adopting the core concepts for use, and their effectiveness, would not only benefit our teaching community but more importantly help improve our students’ understanding of the discipline. The core concepts of physiology have been proposed as a powerful framework that may enhance student learning, and the experience of the four faculty members in this report is an encouraging first step toward their adoption for use in undergraduate physiology education.
Limitations

This report does not include any assessment of student learning outcomes, as it is an interview study based on faculty efforts and their own interpretation of their students’ experience with the core concepts. As a small interview study, the volunteer bias may influence these data and interpretations. Although these are situated in different types of institutions, three of the four faculty members who responded are in the same general region of the U.S., and a regional bias may be present as well. Three of the four faculty members have also been engaged in P-MIG and were thus aware of much of the efforts in developing the core concepts. Finally, two of the authors also served as interview subjects.

This paper is published as part of a special collection/special issue from P-MIG, a grassroots organization that has formed to help develop international programmatic guidelines for undergraduate degrees in the discipline and to serve those engaged in undergraduate physiology or physiology-related programs. To find out more about this collective, or get involved, please visit our website (https://www.physiologymajors.org/) and consider joining our listserv.

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DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the authors.

AUTHOR CONTRIBUTIONS

P.L.C. conceived and designed research; P.L.C. analyzed data; P.L.C. and L.C.A. edited and revised manuscript; P.L.C. and L.C.A. approved final version of manuscript.

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