Putting the guidelines to work: moving from undergraduate physiology curricular guidelines to program development and improvement

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INTRODUCTION

Despite the rapid growth of physiology undergraduate departments, majors, and courses, undergraduate physiology programs are one of the few science, technology, engineering, and mathematics (STEM) disciplines lacking established curricular guidelines or recommendations (48). Curricular guidelines for undergraduate physiology and physiology-related programs would provide a valuable resource for physiology educators and the discipline of physiology at large. Consensus guidelines define fundamental physiology knowledge, concepts, and skills and, therefore, communicate to internal and external audiences the strengths of an undergraduate physiology education. Undergraduate physiology and physiology-related program guidelines would establish cohesive standards and a framework for developing new programs, while concurrently guiding the improvement of established programs. In addition, such guidelines could promote and articulate the benefits of successful completion of a physiology major for career readiness in research, science education, healthcare, and other fields in which a scientific or analytic background is advantageous.

Prompted by the necessity for curricular guidelines for undergraduate physiology and physiology-related programs, as well as providing a network for physiology educators, the Physiology Majors Interest Group (P-MIG) was formed as an independent group of educators and advisors seeking to support and develop undergraduate physiology and physiology-related programs (47). This group conducted a preliminary assessment of curricular requirements of physiology programs (44) and issued a call to action (46). Currently, P-MIG, through an entirely volunteer effort, is developing curricular guidelines for core concepts, professional skills, and advising of undergraduate physiologists, with substantial contributions and feedback from a large variety of physiology educators (9, 14, 24, 39).

When complete, the P-MIG curricular guidelines for undergraduate physiology programs will provide clear recommendations for student learning outcomes for a wide range of physiology programs. These learning outcomes are the foundation of institutional programmatic evaluation and assessment of established programs and the starting point for developing an objectives-based curriculum for new programs. The collection of information across undergraduate physiology and physiology-related programs provides further resources and support for programs seeking to enhance their curriculum, as well as concrete examples of successful or challenging aspects of implementing initiatives to achieve these learning outcomes. P-MIG has started preliminary efforts to collect and disseminate cross-institutional data and individual examples of implementing curricular guidelines (10).

Programmatic Evaluation and Assessment

Learning outcomes outlined in the P-MIG curricular guidelines can be evaluated and assessed at the program level (Table 1). The information attained during evaluation and assessment allows educators to make data-based curricular decisions. These data also equip programs to approach administration or granting agencies for additional resources to improve their undergraduate physiology curriculum.

Individual undergraduate physiology and physiology-related programs can begin to use the P-MIG curricular guidelines by asking, and starting to answer, several questions about their program:
Curriculum Evaluation and Assessment

To determine if and how the current curriculum in an undergraduate physiology or physiology-related program meets curricular guidelines, it is often appropriate to “map” courses and other aspects of the curriculum (e.g., internships, advising approaches, non-credit-bearing requirements). There are many ways to map curriculum, with specific definitions varying across disciplines (45), but for the purposes of early implementation of P-MIG curricular guidelines, mapping involves creating a visual representation of how various learning outcomes are achieved by a program. Effective mapping clarifies program strengths, or perhaps overlap, as well as gaps in the curriculum. Basic curriculum mapping can be conducted with a simple spreadsheet, but more sophisticated curricular alignment tools, including those already in use by some P-MIG members (37), can be powerful curricular evaluation methods.

Determining the degree to which students are achieving each learning outcome throughout the program can also be conducted during curriculum mapping. Preliminary self-defined levels of student engagement can be recorded. For example, the mapping could include visual representation indicating if the expectation for the learning outcome is introduction, development, or mastery in a course or program requirement. However, the ease of this approach must be weighed against the inherent biases of self-reporting (30). In addition, with the rapid growth of undergraduate physiology and physiology-related programs, at various institution types, it is possible educators without a physiology background will be tasked with this analysis and may feel uncomfortable evaluating and drawing conclusions about the curriculum.

A more robust approach to determine the extent students are asked to attain specific learning outcomes is through the assessment of the curriculum using validated rubrics (Table 1). Curricular assessment rubrics provide descriptions of various levels of engagement within a program (23, 29). Rubric validation is conducted through extensive analysis of preliminary data collected using the rubric and typically corroborated by substantial qualitative assessment (12). Once validated, a rubric will provide an accurate assessment of how a program is or is not meeting the desired standards (22). Thoroughly vetted rubrics are also tested and optimized for reliability, a quality indicating the score provided by the assessment is independent or is not meeting the desired standards (22). Thoroughly vetted rubrics are also tested and optimized for reliability, a quality indicating the score provided by the assessment is independent of who implements the assessment or when it is implemented (19). Well-written and validated rubrics are advantageous because most are designed for self-assessment, and such rubrics assist in comparisons of the curriculum to thoroughly vetted...

Table 1. Summary of programmatic evaluation and assessment using the P-MIG guidelines

| Evaluation and Assessment Process | Required Data | Instruments |
|----------------------------------|---------------|-------------|
| **Core physiology concepts**     |               |             |
| 1. Evaluate if and how current curriculum is aligned with curricular guidelines. | Course offerings, syllabi, course learning outcomes, instructor input | Curricular mapping programs or spreadsheets |
| 2. Assess programmatic implementation of curricular guidelines. | Course offerings, syllabi, course learning outcomes, instructor input | Curriculum assessment rubrics |
| 3. Assess students’ knowledge of core physiology concepts. | Student responses, course grades, GPA | Concept inventories |
| 4. Assess student learning experience to determine mechanism of curricular challenges. | Course grades, GPA, student demographics, student perceptions of learning experiences | Student and alumni surveys, focus groups, and interviews |
| **Professional skills**           |               |             |
| 1. Evaluate if and how current curriculum is aligned with curricular guidelines. | Course offerings, syllabi, course learning outcomes, instructor input | Curricular mapping programs or spreadsheets |
| 2. Assess programmatic implementation of curricular guidelines. | Course offerings, syllabi, course learning outcomes, instructor input | Curriculum assessment rubrics |
| 3. Assess students’ ability to implement professional skills. | Student work, course grades, GPA | Skills rubrics |
| 4. Assess student learning experience to determine mechanism of curricular challenges. | Course grades, GPA, student demographics, student perceptions of learning experiences | Student and alumni surveys, focus groups, and interviews |
| **Advising**                     |               |             |
| 1. Identify desired advising outcomes. | Faculty, advisor, and student input in context of institutional advising outcomes. | Surveys, group discussions |
| 2. Evaluate if and how current advising practices support advising outcomes. | Faculty, advisor, and student input, institution and program advising offerings | Advising mapping spreadsheets |
| 3. Assess students’ attainment of advising outcomes. | Faculty, advisor, student, and alumni input | Surveys, focus groups, interviews |
| 4. Assess student advising experience. | Student and alumni perceptions of advising experiences, demographics | Surveys, focus groups, interviews |

GPA, grade point average.

1. To what extent is the current undergraduate physiology curriculum aligned with the curricular guidelines?
2. How are students engaged in achieving the learning outcomes outlined in the curricular guidelines and how are these assessed? Is this level of engagement appropriate for an undergraduate physiologist?
3. How effective is the implementation of curricular guidelines at optimizing learning in a diverse student population? Are the implemented strategies inclusive for all students?

The extent to which programs collect data and assess any of these questions can vary, depending on programmatic need and institutional requirements.
and appropriate standards. Highly reliable rubrics are also accurate for longitudinal assessment of programmatic change over time.

A very successful and effective example of science curriculum rubrics was published (1, 31) by the Partnership of Undergraduate Life Science Educators (PULSE, https://www.pulse-community.org). The PULSE rubrics facilitate the implementation of best teaching practices in undergraduate life science programs outlined in the foundational call to action, Vision and Change (2). Educators can use the rubrics to self-assess their own programs, track longitudinal change, and define specific goals for enhancing their programs. Similar rubrics, for the assessment of the programmatic implementation of undergraduate physiology guidelines, are a likely focus for P-MIG committees in the near future, thus providing educators the foundational tools for identifying strengths and targeting challenges in their program.

Assessment of Student Learning

Mapping and curricular rubrics evaluate how programs intend to operate, but how do we determine whether the implementation of the curricular guidelines is effective for student learning? And is it effective for everyone? Assessment of student learning gains is critical in understanding the effectiveness of any curriculum. P-MIG curricular guidelines are intentionally broad, and therefore versatile, allowing for use in a wide variety of programs. Respective programs must consider if their own interpretation of the guidelines enhances student learning.

There are many, many assessment tools to measure gains in student learning and understanding, which have been thoroughly tested and validated. Tools to assess student gains in content-specific knowledge, such as concept inventories, are validated to ensure scores are representative of actual student knowledge and to eliminate biases (22). Additional reliability analysis confirms if repeated under the same conditions, the assessment would provide the same results (5). Rubric testing and validation require multiple iterations of question development, extensive student and educator interviews, and a large sample size of preliminary participants tested over the course of many years (15, 38). Therefore, P-MIG will likely not focus on developing new direct measurements of student learning gains in the near future, but rather investigate how established tools can be used and modified to assess student learning in undergraduate physiology programs. If educators are interested in evaluating and addressing these research questions at their own institution, consultation with their respective Institutional Review Board and experienced collaborators is essential.

P-MIG core concepts curriculum guidelines build on key physiology principles identified by Michael et al. (27), and were refined with extensive consultation and assessment by physiology educators (26). Concept inventories, validated multiple choice assessment tools designed to evaluate student knowledge of key principles, are common across science disciplines (17, 38). These concept inventories are typically administered pre- and postintervention to determine the direct impact of the intervention. Several groups have developed and validated concept inventories to assess undergraduate student knowledge of core physiology principles (25, 36). Some concept inventories focus on various aspects of the physiology core concepts, such as homeostasis (25), whereas others, such as Phys-MAPS (http://cperl.lasp.cornell.edu/bio-maps), assess undergraduate student knowledge across several core concepts (36). Complementary efforts by the Human Anatomy & Physiology Society (HAPS) established the HAPS Comprehensive A&P Exam (https://www.hapsweb.org/page/ComprehensiveAPEXam) to assess student knowledge, based on HAPS-defined content knowledge learning outcomes for a two-semester anatomy and physiology sequence.

While concept inventories are appropriate for the assessment of student content knowledge, assessment of student learning gains in professional skills must determine whether undergraduates have gained or improved the ability to perform the desired learning outcome (Table 1). With the finalization of the P-MIG professional skills guidelines (14), it would be appropriate to develop or adapt an assessment tool that evaluates students’ implementation, rather than knowledge, of various professional skills. One possible model is the Association of the American Colleges and Universities (AAC&U) Valid Assessment of Learning in Undergraduate Education (VALUE) rubrics (23). This set of 16 rubrics is particularly attractive because it is designed to assess curricular innovation through the evaluation of various types of student work (33). So rather than implementing an exam or survey, educators can use existing student work, such as writing samples, creative work, or presentations, to assess curriculum effectiveness. Once again, best practices suggest pre- and postintervention assessment of student work, ideally in comparison with a control group.

Assessment of the Student Learning Experience

Given the global diversity of physiology and physiology-related programs, it is essential for P-MIG to be a vigilant arbiter of how implementation of the curricular guidelines impacts diverse student populations. As physiology educators conduct programmatic assessment, implement curricular change, or develop new curricula, they must commit to decreasing disparities often observed in STEM education (11, 35).

Traditionally observed disparities in course performance, pass/fail rates, and grade point average (GPA) signal problematic learning experiences. However, these parameters alone do not reveal the cause of the disparity. Furthermore, it is possible for students to have positive traditional indicators of success, such as a high GPA, but still have a negative learning experience. For example, if students feel isolated and lack a sense of belonging within the program or at the institution, their learning suffers (35, 41). This is particularly true for diverse student populations in science (42). The impact of a negative learning experience may or may not affect overall course performance or GPA, but could affect students’ enthusiasm about physiology and persistence through the program.

Educators, in collaboration with experienced researchers, should collect and analyze data about the student learning experience to better understand if and why particular student groups are struggling (28). A mixed-methods approach, using both quantitative and qualitative data to address specific research questions, is the most effective approach when assessing the student experience, particularly within a population of diverse student learners (13, 18). Student demographic information, such as data about race, ethnicity, and gender, coll-
lected in conjunction with various measures of student success, will identify where disparities exist. Self-reported student gains in learning, through such assessment instruments as the Science Education for New Civic Engagements and Responsibilities (SENCER-SALG), provides additional insight into how students perceive their learning and learning environment (7).

Quantitative data can lead to research questions, often best addressed with targeted qualitative data collection from rigorously employed interviews or focus groups (13, 18, 20). For example, if disparities exist in course performance, analysis of qualitative data asking students to describe their sense of belonging in the program or the strategies they employ when struggling in a course may provide critical insight into addressing these disparities. Similar qualitative data collected from alumni can inform educators about the long-term and lasting impacts of the learning environment.

Assessment of Advising Practices

Effective advising increases the likelihood of long-term student success (8). Many physiology educators serve as formal or ad hoc advisors, yet few receive formal training (9). Rapidly shifting national student demographics (43) and the dramatic increase in popularity of physiology and physiology-related majors provides additional impetus for the investigation and development of standards for successful advising of undergraduate students in these programs (6). P-MIG is in the initial stages of identifying and defining guidelines for effective advising for physiology and physiology-related undergraduate programs (9).

Like best teaching practices, best advising practices are driven by desired student learning outcomes (32). While many institutions identify advising outcomes, few formal program-specific advising outcomes are found in the literature (16, 32). Programs seeking to improve their advising must first identify student learning outcomes that best align with the needs of their respective students (Table 1). Typical advising outcomes address what students know, what students can do, and how students connect and articulate the various components of their education (32). For example, programs may want their students to know requirements for the major or professional school prerequisite courses, how to work effectively with other students outside of class, or be able to describe how their courses related to their internship (21, 32). To enhance student success, advising outcomes should also address the overall student advising experience. These advising outcomes could include students feeling they belong within the program and they are supported by faculty, staff, and peers (18). After identifying desired outcomes, programs can evaluate through mapping if and where students are provided the advising to gain the knowledge, skills, and feelings of support to achieve the advising outcomes.

Assessment of if and how students are attaining advising outcomes provides valuable feedback for programmatic improvements. However, current advising assessment practices are typically limited to student surveys (16, 32). Given the importance and multifaceted impact of advising on the student learning experience, the most appropriate assessment is a mixed-methods approach (16). These data could come from standardized national surveys, institutional or programmatic in-house surveys, focus groups, and/or interviews. Given the long-term impact of advising, it is also appropriate to collect these data from both current students and alumni. Therefore, programmatic implementation of future P-MIG guidelines for advising will require quantitative and qualitative assessment to define and determine effective advising within the context of respective programs.

Role of P-MIG in Undergraduate Physiology Program Improvement and Development

Currently, P-MIG is the only organization to collect and analyze curricular data from undergraduate physiology and physiology-related programs across institutions (34, 39, 44, 49). As P-MIG committees move from guideline development toward evaluation and assessment strategies, P-MIG annual meetings and publications serve to disseminate information about how programs are meeting and assessing the implementation of the guidelines. This information provides a critical resource for programs addressing similar or related issues and new programs seeking to define their curriculum. It also promotes further assessment and improvement at these institutions. This iterative feedback informs future versions and revisions of the P-MIG curricular guidelines.

Through the development of consensus curricular guidelines, P-MIG has established expertise in undergraduate physiology curricular design. As P-MIG committees and members continue to advance the assessment of the curricular guidelines, further expertise will emerge. This expertise and data provide the necessary foundation for a programmatic consultation model, with knowledgeable physiology educators evaluating and assisting new and improving programs.

Undergraduate program consultations provide specialized guidance for new and improving programs to implement best teaching and curricular practices. If P-MIG were to pursue a program consultation model, it would likely be based on the internationally lauded PULSE institutional-visit recognition program (https://pulse-community.org/recognition), which implements a combination of programmatic self-assessment, external evaluator visits, and a report of recommendations (29, 31). The primary focus and infrastructure of P-MIG does not currently prioritize housing a formal programmatic consultation model. However, P-MIG is strategically placed to collaborate with organizations seeking to pursue a formal consultation, recognition, or accreditation model. Established science education programmatic recognition or accreditation models, including those offered by the American Society for Biochemistry and Molecular Biology (4) and the American Chemical Society (3), could serve as additional models (46).

Conclusion

Finalized P-MIG curricular guidelines for undergraduate physiology programs will provide the foundation for collecting programmatic evaluation and assessment data (Table 1). These data are essential for the design and implementation of innovations to address and monitor curricular hurdles for student learning. Collectively, these innovations will shape undergraduate physiology education.

This paper is published as part of a special collection/special issue from P-MIG, a grassroots organization that has formed to help develop programmatic guidelines and 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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AUTHOR CONTRIBUTIONS
K.M.J. drafted manuscript; edited and revised manuscript; approved final version of manuscript.

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