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Professional skills for physiology majors: defining and refining

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Submitted 30 December 2019; accepted in final form 27 May 2020

French MB, Choate JK, Zubek J, Bryner RW, Johnson KM, Luttrell MJ. Professional skills for physiology majors: defining and refining. Adv Physiol Educ 44: 653–657, 2020; doi:10.1152/advan.00178.2019 — Changing labor markets require a workforce that is broadly trained for a variety of possible careers. Recognizing this, government and industry representatives, along with students and their families, are encouraging universities and colleges to focus more on developing transferable skills to maximize employability of their graduates. In response, academic institutions and professional organizations have begun to develop lists of transferable professional skills that they expect students to have acquired on graduation. At the 2018 Physiology Majors Interest Group (P-MIG) meeting, participants stated that there was a need to define a list of professional skills for undergraduates completing a physiology major. To this end, a professional skills committee was established. Initially members of the committee worked together to develop a draft list of skills. An iterative process of refining the list was then undertaken through presentations/small-group discussions at appropriate international meetings and via an online survey. Over 60 physiology educators, the majority of whom teach in undergraduate programs, provided input. The final list (presented here) consists of 13 skills grouped in four broad categories: think critically, communicate effectively, behave in a socially and scientifically responsible manner, and demonstrate laboratory proficiency. It is anticipated that the list will be used for curriculum mapping and to guide the development of new physiology courses and major programs. The professional skills committee now plans to develop rubrics and tools that will allow for the assessment of these skills.

communication skills; critical thinking; laboratory proficiency; professional skills; transferable skills

INTRODUCTION

Changing student demographics, competition between universities, and pressures from key external stakeholders, such as government and business, have shifted the focus of universities and colleges beyond the development of discipline-specific knowledge to supporting the employability of graduates. To maximize employability, graduates must demonstrate transferable (professional) skills that are valued by employers. Employers, particularly in science, technology, engineering, and mathematics (STEM), however, indicate that graduates often lack these skills and/or are unable to articulate how their undergraduate training provided these skills (11, 14). This has prompted educators and academic institutions to focus on defining a set of transferable skills that should be developed as part of an undergraduate education to improve the employability of recent graduates, and to establish a narrative of employability for internal and external audiences. To do this, many national and international societies and academic institutions have developed recommendations for the introduction, development, and mastery of broadly defined transferable professional skills.

In the biological sciences, for example, undergraduate core competencies were developed by the American Association for the Advancement of Science and the National Science Foundation, in consultation with the wider biological sciences community, as sets of skills linked to biological practice (2). These core competencies include the ability to apply the process of science, use quantitative reasoning, use modeling and simulation, tap into the interdisciplinary nature of science, communicate and collaborate with other disciplines, and understand the relationship between science and society. The American Chemical Society published a set of skills for chemistry undergraduates, including problem solving, chemical literature and information management, laboratory safety, communication, teamwork, and ethics (3).

In terms of physiology, in 2003, the American Physiological Society and the Association of Chairs of Departments of Physiology described professional skills for physiology “trainees” (4). The focus was predominantly aimed at PhD graduates and postdoctoral fellows, rather than undergraduates, as evidenced by the skills that were included, such as grant writing, interviewing, supervising, and teaching. While these skills are related to academic research careers, the authors also acknowledged the diverse career outcomes of individuals with postgraduate physiology training (e.g., academia, research, government, and teaching).

The numbers of undergraduates studying physiology are increasing (10), with diverse career outcomes for these graduates. This is driven in part by improving employment trends in health-related fields (13, 17). In fact, recent undergraduate surveys indicate that >80% of those who study or major in physiology plan to pursue careers in medicine or allied health areas (7, 8), while others intend to pursue careers in research, academia, and industry. The diverse career paths mean that undergraduate physiology educators must ensure that their courses and programs are designed to help their students develop transferable professional skills.

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Participants at the 2018 meeting of the Physiology Majors Interest Group (P-MIG) agreed that physiology undergraduate programs and course planning and design would benefit from a consensus list of transferable professional skills that are expected for all physiology majors to have developed upon graduation. To this end, the P-MIG professional skills committee was established, consisting of meeting participants with extensive expertise in undergraduate and professional school physiology education, teaching transferable skills, curriculum development, and student mentoring (core members of this committee are the authors of this paper). The purposes of this paper are 1) to describe the work of the P-MIG professional skills committee including its consultation process; 2) to communicate the professional skills that were developed; and 3) to discuss future steps.

METHODS

To begin to develop a consensus list of professional skills, Julia Choate, Randall Bryner, and Michelle French, the co-chairs of the professional skills committee, met via teleconference throughout the fall of 2018. Together, they developed a draft list of professional skills based on skills articulated by their own institutions and others (version 1) (16, 18). Version 1 included the following general categories: critical thinking, communication, behavioral and social skills, and general and specific practical laboratory skills. Version 1 was then sent to the entire professional skills committee in January 2019 for comment. Suggested changes were incorporated into a new draft (version 2) that was shared with physiology educators, including those attending the P-MIG session at the 2019 Experimental Biology National Meeting and the 2019 P-MIG meeting. At both meetings, attendees were given an opportunity to comment and make suggestions during round-table discussions. Based on feedback received, a revised draft (version 3) was developed with the following general categories: critical thinking, effective communication, responsible social and scientific behavior, and demonstrated laboratory proficiencies. Within each category, three to four measurable skills (outcomes) were defined, along with specific examples of each.

Participants at the 2019 P-MIG meeting felt that broader consultation was required to finalize the professional skills list. Thus an online survey was sent electronically to physiology educators (faculty, administrators, specialists, and graduate students) in Australia, Canada, and the United States. Respondents were sent version 3 for comment (an open textbox was provided). They were also asked to rate the importance of each skill, using a Likert scale (1–10, where 10 = most important and 1 = least important), and to state the degree to which their students would be expected to develop the skill based on the following levels: exposed to skill, proficient in skill, or highly proficient in skill. The survey was approved by the Institutional Review Board at Michigan State University as Exempt 1 under 45CFR 46.104(d) (October 14, 2019). Immediately following approval, the survey was distributed to more than 260 individuals who are affiliated with P-MIG via a listserve and direct e-mail. The survey was also sent to the educator group of the Australian Physiological Society (n = 42) and undergraduate coordinators and educators at several Canadian universities who offer major programs in physiology (n = 20). Google Forms was used for ease of use and subsequent data analysis, and potential respondents were given 14 days to complete the survey. The feedback from survey participants was then used to create the final consensus list of professional skills for graduates of undergraduate physiology major programs.

RESULTS

Throughout our consultation process with physiology educators and other stakeholders, there was general agreement on the need to define transferable professional skills for physiology majors and that a consensus list would complement the other program learning outcomes that have/are also being developed by P-MIG and others [e.g., core concepts (12) and curriculum mapping]. The most substantial changes to the list of professional skills were made between versions 2 and 3. Specifically, version 3 was developed based on extensive feedback from participants at the 2019 P-MIG meeting (39 feedback sheets were collected). Note that almost 90% of the participants at the meeting had academic appointments ranging from lecturer to professor positions and >90% work at universities with undergraduate physiology or related programs (5). At that meeting, most participants stated that the specific laboratory skills that had been included in version 2 were not broadly applicable, so this category was omitted in version 3, with selected elements incorporated into the general laboratory skills category. The feedback from the online survey respondents regarding version 3 served to validate the version 3 list of professional skills: there were few suggested changes to the list of professional skills, with most of the proposed edits related to wording changes to the examples. The final consensus list of professional skills with revised examples (i.e., version 4) is found in Table 1.

In terms of the online survey, a total of 35 full responses were obtained from individuals representing 33 institutions in Australia, Canada, and the United States (13.4% return rate; 35/260; United States, 21 respondents; Australia, 7 respondents; and Canada, 6 respondents). Both university and community college representatives completed the survey. Slightly over 69% of respondents represented 4-yr degree programs, 14% represented 3-yr degrees, 11% represented professional/graduate degrees (e.g., veterinary medicine, Doctor of Medicine, Master of Science), and 2% represented 2-yr technical programs (e.g., diplomas). The top three most common types of physiology major programs in which the survey respondents teach are Physiology (14 total), Exercise Physiology/Kinesiology (5 total), and Biology/Biomedical Science (4 total). Just under 71% of respondents have “primarily teaching” duties, whereas 29% of respondents indicated that their duties were primarily administrative/research/service or a combination of the three.

While this survey was anonymous, of the 35 participants providing full responses, 27 voluntarily provided their names, which were compared with the list of 2019 P-MIG conference attendees. Of the 27, 7 also attended the 2019 P-MIG conference and may have also completed the survey conducted at the conference regarding version 2 of the professional skills. In total, however, at least 60 individuals provided input during the development of these professional skills.

In addition to providing written comments on individual professional skills, survey respondents were also asked to rate each skill in terms of its importance and the level of proficiency that undergraduates are expected to reach by the end of their degree. Scores of 7 or higher were grouped into the category of “high importance” (based on a scale of 1–10, where 10 = most important and 1 = least important; note that we chose a score of ≥7 to be of high importance as modeled by previous clinical surveys) (9). Table 1 shows the results from this rating (the rating was based on version 3 skills, but since the actual skill descriptions did not change much from version 3 to 4, the rating results are displayed alongside version 4 skills and
Upon completion of an undergraduate degree in physiology, students should be able to:

1. Think critically

1.1. Apply, analyze and integrate information to generate evidence-based solutions to physiological problems

1.2. Develop arguments, hypotheses, and conclusions using critical analysis of the scientific evidence

- Combine knowledge from more than one organ system to explain complex physiological scenarios including case studies
- Explain research results from laboratories or independent study
- Explain why hypotheses cannot be “proven,” but also how the null hypothesis can be rejected (via statistical analysis)
- Critically evaluate, for example, author credentials, the publisher, relevance of experimental design and conclusions, and identify assumptions and potential invalid arguments
- Formulate appropriate conclusions by correctly interpreting and integrating scientific results from related studies
- Interpret various representations of quantitative data, including graphs, figures, and diagrams, and use appropriate statistical tests (e.g., paired/ unpaired t tests, ANOVA) and relevant software
- Explain the physiological mechanisms underlying experimental data from the whole body to the cellular level
- Select and create the appropriate graphical representation of a data set
- Describe and give examples of the kinds of relationships that occur between variables, e.g., linear relationships, area under the curve, time courses (latencies, peak responses, steady-state conditions)

2. Communicate effectively

2.1. Identify appropriate sources of information, and their application in research and scientific/clinical decision making

2.2. Communicate physiology in writing targeting a broad range of audiences from scientific experts to the lay public

2.3. Communicate physiology orally to diverse audiences in a clear and engaging manner

3. Behave in a socially and scientifically responsible manner

3.1. Behave ethically and with integrity in the sciences and in society

3.2. Work independently, manage time effectively, and be responsible for own learning

3.3. Work collaboratively and cooperatively with others, appreciating and valuing differing views, and the principles of freedom of expression, equality, and social justice

4. Demonstrate laboratory proficiency

4.1. Accurately collect and record physiological data, appreciating the limitations of the measurements and instrumentation

- Calibrate recording equipment
- Demonstrate an understanding of acceptable variation of data
- Perform, analyze, and interpret the results of specific physiological tests that measure the parameters such as: pulmonary function (e.g., FVC, MVV); measurements of cardiac and vascular function (e.g., HR, BP, ECG, force of cardiac muscle contraction); blood (e.g., hematocrit/red blood cell count, lactate, glucose); human performance (e.g., VO_2, muscle strength, muscle endurance, flexibility and body composition). (Note that not all of these are required for a given program, nor is the list exhaustive.)

4.2. Test hypotheses by designing experiments that use appropriate methodology and equipment

- Design experiments (to test a hypothesis), identifying the main variables (which may interact), controls, and replicates, along with the possible limitations of the approach

4.3. Understand and demonstrate ethical treatment of experimental animals and human subjects

- Be familiar with the local, national, and international codes and guidelines for the ethical treatment of experimental animals and human subjects

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Table 1. Final version of professional skills for physiology majors

| Examples | High Importance* | Highly Proficient or Proficient† |
|----------|------------------|----------------------------------|
|         |                  |                                  |

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*Importance*

Highly Proficient or Proficient†
examples). In general, the ratings indicate that all skills are important, and the majority stated that they expect that their students would be proficient or highly proficient in each skill on graduation.

Only very small percentages (1–2%) rated some skills unimportant or stated that the skill was not addressed at all by their program. On closer inspection of the data, this appears to be a sole respondent who rated skills 2.1: identify information sources, 2.2: written communication, and 4.1 and 4.4: demonstrate laboratory proficiency skills, as both “not necessary” and “not an expectation” for their clinically oriented students or program.

In terms of responses from different countries, the importance of certain skills was rated 20% higher by respondents from Australian/Canadian institutions in comparison to those from American institutions (specifically: 1,3: interpret data, 2,2: written and oral communication, and 4,3: ethical treatment of subjects). As well, Australians rated skill 4.2: developing a hypothesis and experimental design, as slightly higher in importance than responses from American and Canadian institutions, but much lower in proficiency by 17%. The number of respondents from Australia and Canada, however, was small (n = 7 and n = 6, respectively) and disproportionately represented larger research-intensive institutions, making it difficult to draw broad conclusions from the country-specific data.

**DISCUSSION**

Given the iterative and broad consultation process that we have undertaken, we consider that Table 1 represents the final version of the professional skills recommendations, barring periodic review and update. It is important to note that physiology major and related programs can differ widely: some focus on preparing students for research, while others focus on health and clinical-related fields. In addition, educational resources, such as laboratory equipment and instructor expertise, can differ greatly between departments and institutions. Thus our list of professional skills should provide guidance rather than being used for formal accreditation purposes. Establishing consensus and recognized guidelines for professional skills in conjunction with the core concepts and advising guidelines for undergraduate physiology majors, however, does provide structure for curricular development and focuses on specific student outcomes.

The P-MIG professional skills list with its focus on critical thinking, communication, and behavioral and social skills aligns well with guidelines developed by other discipline-specific organizations and academic institutions (2, 3, 6, 16, 18). For example, all of the non-content-related core competencies defined by the American Medical Association for entering medical students are reflected in the P-MIG professional skills list (6). The laboratory category is somewhat unique for these types of guidelines but is appropriate given the clinical and research nature of physiology and the wide range of careers for physiology graduates that require these types of skills. It is in this area, however, that individual major programs will likely differ the most, depending on laboratory resources and expertise available at the institutions, along with the potential specific needs of graduating students (e.g., those following clinical vs. research careers).

We note that, for all skills, the perceived importance was rated more highly than the expected proficiency in the skill on graduation. Skills with the greatest difference (>15%) were developing and testing hypotheses, recording and analyzing data, understanding laboratory health and safety, and ethics. Possible reasons for this difference include: 1) students might not currently have opportunities to develop these skills (e.g., programs might not offer laboratory courses); 2) more traditional physiology programs often emphasize knowledge transfer rather than developing transferable skills; 3) acquisition of proficiency in transferable skills occurs throughout life; thus the lower estimates of proficiency likely acknowledges that students are at the start of this journey; and 4) it can be difficult to benchmark or generate standards for assessment of these skills. As stated later in this paper, identifying and developing standard assessment tools is the next task of the committee. We believe, however, that the consensus list of skills that we have developed will prompt physiology undergraduate program coordinators to map their programs and courses in terms of these skills and to consider new and additional methods of instruction in these areas.

A somewhat surprising result was that one of the lowest rated skills overall was “test hypotheses by designing experiments that use appropriate methodology and equipment” (77% importance, 48% proficiency), especially since the “ability to apply the process of science,” including generating and testing hypotheses is a core competency articulated by *Vision and Change* (2). It is likely, however, that this reflects the fact that this skill was listed in the “demonstrate laboratory proficiency” section of the survey, and that some of the respondents teach in programs without hands-on laboratory courses or independent research opportunities. In fact, the respondents do think that the ability to apply the process of science is important and should be developed by whatever means possible. Specifically, respondents rated the think critically skills, 1,2: develop arguments, hypotheses and conclusions using critical analysis of the scientific evidence, and 1,3: analyze and interpret physiological data using appropriate methodology, quantitative rea-

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**Table 1.—Continued**

| 4.4. Understand and follow the occupational, health and safety protocols within the physiology laboratory | Examples | High Importance* | Highly Proficient or Proficient† |
|---|---|---|---|
| ● Explain and follow institutional and national guidelines for occupational health and safety, including universal precautions for the handling of biological samples | 80 | 60 |

Values are percentage of respondents. BP, blood pressure; FVC, forced vital capacity; HR, heart rate; MVV, maximal voluntary ventilation; \( \dot{V}_{O_2} \), \( O_2 \) uptake. *Percentage of respondents who rated the skill at 7 or higher (on a scale from 1 to 10). †Percentage of respondents who indicated that students should be “proficient” or “highly proficient” at the end of their degree.
soning, and statistics, highly (skill 1.2: 91 and 77%, and skill 1.3: 83 and 74%, respectively, in terms of importance and proficiency; see Table 1).

The P-MIG professional skills guidelines will assist at multiple levels, including that of an individual learner, and at the course, program, and across physiology program levels. The latter two, assessment of physiology programs and reporting practices across physiology programs, will take precedence in the next steps for the P-MIG professional skills committee. Development of assessment tools around individual learning and course outcomes will likely take place in collaboration with other stakeholders, within and beyond P-MIG, in the future.

A typical first step in programmatic curricular assessment is the mapping of current and/or desired curricular offerings onto the guidelines. This provides a visual representation of which guidelines are being supported by the curricular offerings, as well as revealing gaps in the curriculum. One tool for such mapping is the electronic curriculum mapping system (e-CMS)/Physio alignment database (15), which provides a step-by-step guide to creating course objectives/competencies and aligning them with course curriculum. It also helps to identify and tag objectives in curriculum alignment projects. One future direction is to include P-MIG professional skills in this mapping tool.

Programmatic assessment can occur with rubrics for curricular and programmatic alignment with the guidelines. Program assessment with rubrics allows for summative and formative longitudinal assessment and evaluation and are often conducted by external evaluators, independent of the program and institution. A potential model for this type of assessment is the Partnership for Undergraduate Life Sciences Education model, which provides rubrics and consultations for institutions looking to implement reforms outlined in Vision and Change (1, 2).

The P-MIG professional skills committee will now focus on the development and validation of curricular mapping tools and rubrics for programmatic assessment of the P-MIG professional physiology skills. It is possible that P-MIG can serve as a conduit for collecting and disseminating data from physiology programs about how they are designing and implementing their curriculum to meet the professional skills guidelines. This, in turn, will provide a critical resource for new undergraduate physiology programs.

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.

DISCLOSURES

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

AUTHOR CONTRIBUTIONS

M.B.F., J.K.C., J.Z., R.W.B., K.M.J., and M.J.L. conceived and designed research; M.B.F., J.K.C., and R.W.B. performed experiments; J.K.C., J.Z., R.W.B., K.M.J., and M.J.L. analyzed data; M.B.F., J.Z., R.W.B., K.M.J., and M.J.L. interpreted results of experiments; M.B.F., J.K.C., and J.Z. drafted manuscript; M.B.F., J.K.C., J.Z., R.W.B., K.M.J., and M.J.L. edited and revised manuscript; M.B.F., J.K.C., J.Z., R.W.B., K.M.J., and M.J.L. approved final version of manuscript.

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