PRAC Report: Assessment of Student Learning
IUPUI School of Science
2019-2020 Report

Overview: The School of Science at IUPUI provides outstanding science education for all IUPUI students, education in depth for students in our School, and engages in fundamental and applied research in the physical, biological, mathematical, computational, and psychological sciences to increase knowledge and advance the development of the sciences at IUPUI and in the State of Indiana. Within the seven academic departments (Biology, Chemistry & Chemical Biology, Computer & Information Science, Earth Sciences, Mathematical Sciences, Physics, and Psychology) and the three programs (Artificial Intelligence, Forensic and Investigative Sciences and Neuroscience) of the School, there are over 125 full-time faculty members. The School is the academic home of ~2,500 undergraduate majors, ~400 graduate students, and ~125 post-baccalaureate pre-professional students.

Part I: Student Learning Outcomes for Each Academic Program

The School of Science has been utilizing the Student Learning Outcomes developed during the 2010-2011 academic year for assessing each academic program. **IN Fall 2021, each undergraduate program reviewed and reaffirmed their student learning outcomes.** A comprehensive list of SLOs for both undergraduate and graduate education and degree programs can be found in the IUPUI Bulletin. In Spring 2019, each program mapped its program level learning outcomes to the new IUPUI Profiles of Undergraduate Learning.

Undergraduate SLOs (B.A. and B.S.)	**Graduate SLOs (M.S. and Ph.D.)**
• Biology • Chemistry • Computer and Information Science • Environmental Sciences • Forensic and Investigative Sciences • Geology • Interdisciplinary Studies • Mathematics • Physics • Psychology • Neuroscience • Artificial Intelligence (new as of Spring 2021)	• Addictions Neuroscience • Biology • Chemistry • Clinical Psychology • Computer and Information Science • Geology • Industrial Organizational Psychology • Mathematics • Physics • Applied Social and Organizational Psychology • Computational Data Science • Forensic and Investigative Sciences

https://bulletins.iu.edu/iupui/2021-2022/schools/purdue-science/index.shtml

How is the School of Science assessing Student Learning Outcomes and Student Learning?

There are several ways that the school has been examining their curriculum and working on course improvement. They are organized in the sections below. First, we have continued to have our general education courses reviewed. Second, various programs have been conducting course improvement activities. Third, departments have received SEED money from SIERI to examine new practices in STEM Education. Finally, faculty share new and best practices in the classroom in our annual STEM education summer showcase.

Part II: Assessment and Continuous Improvement Plans in General Education Courses.

The main focus of this School of Science's annual report is on the efforts undertaken in the last year to assess and develop improvement plans related to student learning outcomes for our *general education* courses. The School of Science has 80 courses on the general education list. Over the last five years, we have had 80 courses reviewed. To gain reapproval, departments must submit a dossier that includes the learning outcomes, and evidence of student attainment of the outcomes. In addition, departments provide information and reflection on DWF rates and submit a plan for continuing improvement. The following data and information provide evidence that we are assessing our programs, and that we are addressing the IUPUI Profiles of Undergraduate Learning and Principles of Graduate Learning in the context of our courses.

Below are excerpts from some dossiers submitted to the Gen Ed Review Process in AY 2020-2021. Various parts of the dossiers were selected to provide evidence of the attention paid to learning outcomes, assessment, and continuous improvement throughout the Science curriculum.

Physics 21800

Most of PHYS 218 students are engineering technology majors. One of the strongest motivations for this course is to train students to understand and appreciate the underlying physical mechanisms in nature, and connect them to their own field of study. PHYS 218 and 219 are often the first interactions with physics these majors will have had since high school, and beyond that no other core physics courses are required unless the student chooses to take an elective class. Coming in, many of the students struggle to see or appreciate the connections between the lectures and the real life, even though it is regularly emphasized during the those sessions. In addition, since the instructors typically come from a more traditional physics background, the examples given in the class tend to reflect those viewpoints strongly. We have started including examples rooted in cross-curricular topics such as biomechanical analysis of movements or heat and efficiency calculations of automobile engines, to explain the different concepts in Physics for this course and have received positive feedback from students. The teaching of PHYS 218 mirrors that of PHYS 219 not only because of its lecture, recitation, and laboratory structure, but also in its degree of faculty involvement. One faculty member teaches all of the lectures, several instructors instruct the recitation sections, and grade the exams during the Fall and Spring semesters. A group of faculty such as this provides a "check" on the content of the course to ensure it adheres to the accepted curriculum. Efforts at continuous improvement are based on improving students' performance on exams, problem-solving abilities as witnessed in recitation, written student reviews of the course, and other mechanisms such as informal discussions with students. Based on student responses from previous semester, there are three general areas about which many students had raised concerns: 1) The level of difficulty: A common critique of the course is its difficulty of exams (i.e., that they should be shorter in length or consist of easier questions.) To that end, the current format does not rely any longer on strictly quantitative free response questions. A qualitative free response section has been added to allow the students to demonstrate mastery through their words as well. We use Mastering Physics for the homework. This provides a direct connection to the problems being presented in the book. 2) Implementation of interacting learning method and the educational technology: From the student survey (included in the review), about 75% of the students felt that this course was improving their problem-solving skills. One of our educational researchers (Dr. Gavrin) has also found that most students favor the use of interactive educational technology (i.e., Course Networking) and tend to raise their grades as a result. Given Dr. Gavrin's research, the department will continue to use such technology for years to come. Currently, we are using MasteringPhysics for its online homework technology and other educational resources. Over the past ten years, we have changed technology through the yearsprimarily to improve the quality and, secondarily, to reduce the cost per student. 3) Difficulty with problem solving in Physics: A similar critique that was noted within student comments in the end-of-semester instructor's course evaluations was to place a greater emphasis on solving problems during the lecture sessions. As a result, the number of problems solved in the lecture class has been increased in Fall 2020. The problem is broken down into smaller, segmented pieces. The students are asked to solve the questions in small groups, and then the correct solution is demonstrated, once again tying the problem to the theory they have just been taught. This method has proven effective.

Psychology B205 Introduction to Statistics

PSY-B 305 Statistics Student Reflection We sent a Qualtrics survey to students enrolled in B305 containing the reflection questions and offered them 5 extra credit points for completing the survey. Of the 210 students originally enrolled in the course, 181 (86%) wrote responses to the reflection questions. All student responses are included in Appendix B. Reflection Questions 1. How has your understanding of statistics changed since taking this class? 2. How has the material learned in this course influenced the way you analyze and evaluate information you encounter in the world? Please include specific examples to illustrate your answer. Analysis of Responses Responses to the reflection questions indicated their progress toward two of the IUPUI Profiles of Learning for Undergraduate Success: Problem Solver and Communicator. In responding to the first question, students evaluated the knowledge they had acquired and mastered in the course. Specifically, they reflected on their understanding of fundamental statistical concepts, mastery of different statistical techniques, and their ability to apply those different techniques to answer specific research questions. All of these are specific learning objectives related to becoming an effective Problem Solver who can analyze information, think critically, and synthesize information into a coherent whole. Answering this question also allowed students to reflect on their ability to effectively evaluate information and convey their evaluation effectively, which are aspects of becoming a good Communicator. Answering the second question required students to reflect on how their newly acquired knowledge about statistics will affect how they interpret and use information they encounter going forward in their lives, including statistics they consume in the news and research literature. Being able to critically evaluate information is important for becoming a Problem Solver and a Communicator. Understanding of Statistics The majority of students described significant changes in their understanding of statistics as a result of taking this class. Several students commented on the theme of developing specific technical skills, including better understanding of statistical terminology. For example, one student responded: "Now that I understand statistical terms and analyses (such as variance, correlation, binomials, and chi squared)…" Other students described acquiring specific skills in using software (i.e., Excel) to make charts and graphs. One student wrote: "It has also helped me grow my knowledge of Excel and navigating/understanding graphs to find conclusions such as the t-test." Still others commented on how they had achieved understanding of how and when to use which specific statistical test and how to report the results in APA style. For example, one student replied: "I got to learn how to analyze data and write in APA format along with learning how to use Excel throughout the semester." A second theme that emerged in the student responses to the first question was that they had gained a better conceptual understanding of the ideas underlying statistics. One student noted that their understanding of probability theory had improved from taking the course: "My understanding has greatly improved. I have struggled with probability since high school and this class was structured and taught so well that it seemed easy."

Plans for Improvement Based on Student Reflection Given the majority of student reflections were positive, we plan to continue with the current focus of the course. However, some comments from students with previous exposure to statistics noted that the course content was largely review for them or merely reinforced concepts that they already understood. Therefore, we plan to incorporate some optional opportunities to study and apply more advanced statistical concepts, such as moderation, multiple regression, and missing data analyses, so that these students are able to take their learning to the next level. This will be particularly important for students who plan to go on to graduate studies that require the use of advanced statistical techniques. Many students commented on the value of understanding the underlying concepts in statistics and not just focusing on "number crunching." Hence, we plan to increase our focus on conceptual understanding (i.e., why we do things this way) and assessing this conceptual understanding. Finally, given the student enthusiasm for applying course content to current events (i.e., the pandemic and the election), we plan to purposefully add examples and problems to the course that use ongoing world events. We believe this will increase student engagement and make a clearer connection between achieving the course objectives and improving students' abilities to critically consume information they encounter in the world.

Physics 21900

Use of Evidence of Student Learning for Improvement

In this course, the student learning is tested using multiple methods. Formative assessment methods (Think pair share, quizzes, and in-class activities) are used within each semester to make "short term" adjustments in instruction, whereas summative assessment tools (exams, particularly the final) are used to make adjustments between semesters. Note: These methods are described as they are typically used during face-to-face classes. Some additional modifications were used to adapt these methods to synchronous and asynchronous instruction during the pandemic.

Modified Think-Pair-Share method (TPS) According to many studies, active learning methods in which students collaborate with one another are highly effective compared to faculty-centered lecture methods. Engaging students in group discussions/activities, debates, group assignments, etc., all fall into this category. TPS is a collaborative learning strategy, which we have slightly modified to suit this course. Our implementation follows the strategy below.

1. A question is presented in class based on what has been taught. This question is typically posed in form of a multiple-choice question. The students are first encouraged to think about the problem on their own ("think") and answer the question using a colored ABCD card provided at the beginning of the semester. This gives the instructor a fairly good idea regarding the number of students who grasped the concept correctly. 2. If most students get the answer correctly, then the answer is explained once more by the instructor, and the next question is posed. 3. If at least 25% answer the question incorrectly, the instructor explains the topic again and sometimes gives useful hints. This time the students are supposed to make small groups ("pair") and share their ideas with their classmates ("share"). This leads to interesting debates, makes the class more engaging and interesting for the students. 4. Based on their discussions, the students are once again asked to vote. It has been noticed that the students often get the correct answer after they have discussed their answers with another student, leading to the idea that collaborating is one of the most efficient ways to learn a subject.

Quizzes: Once a week, students are given a quiz based on what they have learned that week.Typically, the quiz takes between 3-5 minutes to complete. This provides the students with checkpoints along the way and helps them identify the topics they need to learn better. This also provides feedback to the instructor about how the students are doing on a particular topic. If need be, they revisit the topic once more in class. Activities during recitation sessions: In addition, recitations provide a more casual way of gauging overall student performance. The class is typically given four to six word-problems. The students may work in groups and use the formula sheet, the textbook, and any other print resources to solve the problems. They may not use the internet. Those groups struggling to solve these problems may confer with an instructor. One of the advantages of this type of recitation is the interaction between the instructors and the students. In many ways, these sessions resemble a tutoring session or a one on-one meeting with an instructor during office hours. Since the students in PHYS201 are from non-Physics background, each problem is solved on the board step by step after the students have attempted it.

Exams: Students take three regular semester exams and one comprehensive final exam (the final is described in detail in this portfolio, in Boxes 3.C and 3.D). Each regular exam consists of multiple-choice questions, which test their knowledge of concepts as well as problem solving, and free response problems, which test students' abilities to solve multistep word problems using the formulas provided on the formula sheet given with each exam. The final is double in size and consists of only multiple-choice questions which test their knowledge in both concepts and problem-solving.

Computer Science N211 Introduction to Data Bases

<u>Midterm Survey</u>

A standard mid-term survey is conducted to collect student feedback on their experience in the first half of the semester. The survey result is used by instructor as a guidance to identify areas of improvements. Below are questions on the survey and the file is included in the Box folder named "4. Student Feedback and Course Improvement/A. Evidence of Student Feedback".

1. On a scale of 1 – 5 with 5 being most difficult, what was the difficulty level of questions on the mid-term exam?

2. On a scale of 1 – 5 with 5 being most helpful, how helpful are lectures or your notes in answering exam questions?
3. Which questions on the mid-term exam do you think are most difficult to find answers from class materials?
4. On a scale of 1 – 5 with 5 being most helpful, do you think the midterm exam review was helpful?
5. Which topic(s) do you find most difficult to understand?
6. What suggestions or comments do you have for the instructor to improve your learning experience?
7. What suggestions or comments do you have for the teaching assistants to improve your learning experience?

End of Semester Course Evaluation

End of semester course evaluation results are treated seriously. They are often used as guidance for future teaching. Below are a few examples on how course materials were modified based on students' written comments.

"Exam questions are extremely poorly worded and it is very unclear what is being asked." – Spring 2017

Response: The instructor sent all mid-term and final exam questions to IUPUI TCM Writing Center and corrected ones that were confusing.
Later she worked with the course coordinator when making changes or adding new questions.

"I enjoyed this class and I really liked my professor, but I sometimes felt like the course was moving too fast for an intro course." – Summer 2019

Response: The instructor makes sure both Teaching Assistants hold online help sessions at different times. She will constantly remind students of the TA help sessions and instructor help sessions and encourage students to seek assistance whenever they need help.

"This was an online class. There were PowerPoint presentations to review course material but no additional resources to supplement the PowerPoint presentations. The PowerPoint presentations were not structured well enough to stand alone."- Summer 2019

Response: The instructor checked the overall structure of Canvas materials and made some minor adjustments to help students find materials, including additional resources.

Other adjustments made based on feedback include but are not limited to:

- Assignments were changed to reflect new technology and applications
- Slides were updated to better convey ideas and information
- Topics such as "Big Data" and "Data Security" were added
- In-class assignments were used to encourage more student engagements
- Short tutorial videos were made assisting students using campus recourses such as software downloading and installation, using IUanyware, using Zoom, etc.

Feedback from Teaching Assistants

The instructor maintains close contacts with teaching assistants, usually meets with them once a week asking for feedback to identify students who need additional help.

Feedback from Tutoring Service
Department walk-in tutoring service is conducted in a computer lab. Students will sign in at the teacher's desk with their name, course number, instructor name, and topic where help is needed. The topics listed on the sign-in sheet is a good indicator of difficult areas. The instructor can check with the tutors at any time to see who has come in for what help. The course coordinator collects information at the end of semester and pass it on to course instructors. Below is a snapshot of the sign-in sheet.

Part III: Course Improvement and Assessment Activities

B110 – Introductory Psychology

Several changes have been made to B110 in response to the pandemic. In an effort to provide flexibility and to handle frequent student absences, instructors have been encouraged to give students access to pre-recorded lectures that had previously been made available only to students enrolled in the online/asynchronous sections. It is standard practice to have a quick assessment, a concept check, during every class session. These activities encourage application of content and allow instructors and students to regularly assess understanding of material. Many instructors have converted these from hand-written, in-class submissions to an assignment still completed during class but submitted through Canvas so that students who are absent can still participate and not fall further behind. Exams, which had previously been administered in the computer testing lab, are now taken at home on Canvas. Students have a time limit and agree to an honor code statement at the beginning and end of every test.

The decision to make these changes was based in part on data collected during Spring 2020 by Tina Chen and myself on the impact of the pandemic on student learning (see Herold and Chen, 2021). Students reported an increase in personal and school responsibilities, increase in stress level, and decreased ability to focus at the onset of the pandemic.

However, I was concerned about how these changes may have impacted factors like student engagement, motivation, and ability to understand course content. As a result, I collected some additional data during Fall 2021 in my own B110 section to assess students' perception of and satisfaction with the added flexibility described above. The majority of students (69%) reported that they had to miss at least some class sessions due to illness. Ten percent of students in my single section of B110 reported having to deal with either a serious family illness (e.g., cancer diagnosis) or the death of a close relative or friend. The majority of students felt that the flexible nature of the class (e.g., ability to watch prerecorded lectures if absent and participate in concept checks online) either did not impact or increased their level of motivation, level of engagement, and ability to understand course content. Sixty-six percent of students felt that having online assessments (including weekly quizzes and unit exams) was a more accurate assessment of their knowledge than in-person exams would have been. Ninety percent of students recommended continuing to offer the same level of flexibility in future semesters.

This semester we have added a course reflection assignment to meet the requirements of the Mile Marker assessment for the Gen Ed review. Other changes include that the B110 learning assistants are offering mainly online office hours instead of focusing on just visits to the Psychology Resource Center as fewer students were attending these hours.

Herold and Chen. (2021). Switching from face to face to online instruction midsemester. Journal of teaching and learning with technology, 10, 321-336.

Physics Curriculum

1. Another large effort is reform of all our introductory level labs. We have a new SEIRI Seed grant and additional $'s from a project at IUB that Vic Borden is leading. We spent most of last summer redesigning the labs for all three mechanics courses (21800, P201, 15200) and piloted the changes last fall in P201 and 15200. We have some data (in last semesters course evaluations, plus one pre/post quiz), but nothing properly crunched yet. All three courses using the new materials this spring. Our plan is to spend summer 2022 tweaking what we did, plus preparing revised materials for the three electricity and magnetism courses (21900, P202, 25100) for use starting fall '22. Attached are slides from the first (and only) talk on this project thus far.
2. At a much earlier stage, Ricardo is leading an effort to revise the upper division curriculum. I've cc'd him in case he wants to comment on this or add anything else. At present, he has asked everyone who teaches 300 and 400 level courses to submit syllabi, HW and other artifacts, and putting together a committee to consider changes. An example would be to revise or replace our "Modern Physics" course, which covers exclusively material 90 years old or more.
3. Maybe tangential, but we have also changed some aspects of learning support:
    1. Moved the Physics Learning Space (PhyLS) to a new, larger location (I think that was complete by this time last year)
    2. Established "communal office hours." Rather than each of us having "private" office hours in our office, we all have office hours in LD019 (the older, smaller PhyLS). Any student can come ask whoever is there about any class. We now have a Learning Env. Grant to remodel that space.

See Gavrin, Vemuri, and Maric (2021) in Appendix.

Biology Assessment of Student Learning Outcomes

The biology Department surveyed junior and senior Biology majors in the Fall of 2021 to gauge student satisfaction andallow them to assess their abilities in each of our major departmental Student Learning Outcomes for biological concepts and applied skills and found that, overall students are satisfied with their education in the Department of Biology and identified areas that will requiresome focus. There were 64 respondents, which were mostly female (78.43%), traditional students (81.36) who enrolled at IUPUI at or before the age of 19 (81.36%) and did not transfer into IUPUIfrom another institution (64.06%).

Student self-assessments in biological concepts (1-5 Likert scale) showed that students were confident in their ability to apply the biological concepts of *molecular biology, cell biology,* and *genetics* (4.24, 4.35, and 4.24, respectively) but were less confident about their ability to apply the biological concepts of *physiology, ecology,* and *evolution* (3.67, 3.44, and 3.65, respectively). These results bolster suggestions that the curricula should increase focus in physiology, ecology, and evolutionary biology.

Student self-assessments in applied skills (1-5 Likert scale) showed that students were confident in their ability to apply the skills of *scientific inquiry* (4.67), *quantitative reasoning* (4.59), and *common laboratory equipment and skills* (4.65). The high confidence in applied skills mirrors the open-ended comments in the survey that the labs were a valuable part of their education.

Overall satisfaction was lower than student self-assessments of their ability to apply biological concepts and applied skills. For the prompts "Overall, the IUPUI Department of Biology has prepared me for my career" and, "Overall, I am satisfied with the education I received in the IUPUI Dept. of Biology", 47.62% and 40%, respectively, answered either *Somewhat Agree* or *Strongly Agree.* 23.81% percent answered *Strongly Disagree* for the former and 20% answered *Strongly Disagree* for the latter. In the open-ended narratives, laboratory and quantitative skills were the most frequently mentioned strengths; updating intro classes/labs and low course selection/diversity were the most frequently suggested improvements. Students also provided many valuable suggestions about how we could work to strengthen the department through enhanced laboratory experiences focusing on applied skills, DEI initiatives, and increasing the course offerings. This was a Biology-developed survey so we cannot compare our students' level of satisfaction to that of other units. Nevertheless, this survey has given us insight into our students' opinions about their education that we can use to improve the quality of their experience.

Part IV: SIERI

Faculty from 3 departments received STEM Education Innovation and Research Institute (SEIRI) Seed grants to examine student success in their classes.

Engaging Undergraduate Students in Geo-Equity Challenges

Kathy Licht, Catherine Macros, Gabe Filippelli, Dept of Earth Sciences

Recent studies show that participation of people from underrepresented groups, including Black, Indigenous, Latinx, and other People of Color in geosciences is the lowest among the science, technology, engineering and mathematics (STEM) disciplines (e.g., Huntoon et al., 2015; Stokes et al., 2015; Dutt, 2019; Dutt, 2020; Hofstra et al. 2020; Marín-Spiotta et al., 2020). This lack of diversity, inclusivity, and equity in geosciences must be addressed if the field is to expand and thrive by attracting talented and empathetic scientists that better reflect the country's demographics. This project was created to engage undergraduate Earth Science students at IUPUI in discussions about issues related to equity and ethical decision making in geosciences through the creation of three Geo-Equity Challenge Modules. Geo-Equity Modules (GEMs) are classroom activities centered around real-life case studies involving environmental issues associated with ethical and equity-related issues. The activities were designed to be completed in one 50-75 minute class period after students complete a homework assignment based on content in one of the GEM case studies.

In summer 2021, three case studies were created by 5 student interns, a cohort of interdisciplinary undergraduate and graduate students. The GEM topics were: (a) lead contamination in east Chicago, (b) uranium mining and the Navajo Nation and (c) sea ice and the Pangnirtung Inuit Tribe. All students worked as a team on each GEM and created a website with a narrative and graphics that provide background content for individual student reflection and class discussions. All three modules were used in classrooms in fall 2021. The majority of students reported that their experience in the activity helped them to understand the ethical issues surrounding decisions about some environmental policies (58% strongly agree and 32% somewhat agree).

Improving student achievement in General Chemistry

Partha Basu, Marie Nguyen, Lin Zhu, and Peggy Stockdale

The achievement gap between the well-represented and underrepresented students continues to be one of the most urgent and intractable problems in higher education. Rising income inequality and lack of economic mobility inflict a social strain and is exacerbated by underrepresentation in professions with higher lifetime earning potentials such as science, technology, engineering, and mathematics (STEM). In these disciplines, the underrepresented minority (URM) students' average performance is lower than those who come from a well-represented group with the same academic preparation causing a higher level of attrition. One of the reasons students drop out of STEM majors is their first-year experience, particularly poor performance in first-year courses. general chemistry is a first-year foundational course that is taken by virtually all STEM students. At IUPUI, Peer Led Team Learning (PLTL) has been in place since 1998 for general chemistry I (C105) and since 2016 for general chemistry II (C106), and this pedagogical approach has made a significant impact in student learning as evidenced by a precipitous drop in the DFW grades. We have analyzed the DFW grades in general chemistry obtained by IUPUI students since 2015. The data revealed a disproportionate number of underrepresented students are left behind despite the PLTL program's success. This revelation prompted us to propose an additional intervention discussed in this proposal. In the first step, we will identify students who are 'at risk' of receiving a DFW grade in general chemistry. Indeed, in collaboration with the Institutional Research & Decision Support (IRDS) staff, we have developed a model based on incoming students' scholastic indicators such as GPA, math SAT score (where applicable), and chemistry placement score. Once identified, selected students will be invited to attend voluntary sessions (intervention) that are focused on improving self-efficacy and growth mindset. These sessions that we call ‘Roar In Chemistry’ (RIC) are designed similar to PLTL but focus more on self-efficacy.

Although the first pilot study had small numbers, the data suggested that students who went through the intervention did perform better. The group is conducting a second study this year with stronger recruitment efforts to gain a larger sample size.

Restructuring the Physics Introductory Labs

Gautam Vemuri, Andy Gavrin, Brian Woddahl, and Aparajita Sengupta

The focus of the project is on a complete restructuring of the labs that accompany all six introductory Physics courses offered by the department. These courses are required of all Physics and engineering majors (calculus based 15200 & 25100); almost all science majors (algebra based P201, P202); and many technology majors (algebra based 21800, 21900). Combined, these courses serve approximately 1800 students each year. Every single faculty member, as well as most grad students in the Physics department, participates in one or more of these courses by teaching lectures, recitations, and/or labs. The principal goals of the project are (i) to promote critical and analytical thinking, and quantitative analysis, and (ii) to explicitly include experimental design and communication skills in the student learning goals. To accomplish these goals, we are changing the format of the labs by (i) replacing many single period experiments with experiments extended over multiple weeks, (ii) incorporating technology enabling students to take data outside the confines of the lab, and (iii) requiring students to submit formal lab reports, rather than worksheets.

The current curriculum is too focused on following “cookbook” procedures in all aspects of the lab. Students are not asked to think through what data must be acquired, how it should be analyzed, or what a reader would need to understand the results. Also, since the students works in groups of three to four (due to lack of adequate lab stations and instructors), some students watch passively as their group mates engage with the apparatus. Our project will restructure the labs so that some experiments will be done over two, three or four weeks, with students working in pairs. Students will not be given detailed recipes; rather, they will engage in an iterative cycle with their instructors, during which they will design and refine their experiments, carry out the experiment and analysis based on their growing understanding, and report their results in draft and final reports. Some experiments will be done off-campus, with experiments designed to use capabilities of smart phones. Other on-campus labs will use existing apparatus or more sophisticated mobile sensors. The impact on students as well as the assessment of the project will be done through existing, nationally normed, peer-reviewed assessment instruments, as well as surveys that will be developed as part of the project. Once the restructuring is completed, it is expected that students who take these labs will develop the confidence to undertake laboratory work, design optimal experiments for measuring desired quantities, and communicate their work in a scientifically accepted manner.

This project has some initial data, but the studies are not fully complete.

Part V: STEM Education Showcase

For several years, Dr. Brenda Blacklock has organized and hosted a summer teaching showcase. Faculty who would like to share new innovations from their classrooms conduct short presentations.

Below is the slate of speakers and topics for Summer 2021.

Speaker	Title
Brenda Blacklock, CCB	Introductory Remarks
Tina Chen, PSYCH	Zooming from 0 to 180: Virtual Flipped Classrooms During the Pandemic
Jenny Nelson, ES	A year online: Does it change the way we teach in the future?
Thomas Rossbach, ES	Getting Away from Definitions – Encouraging Higher Order Thinking in F2F and Online Courses
Forrest Brem and Pat Clark, BIOL	Sequence course alignment to increase enrollment, student success, and student satisfaction.
Patrick Gentry, BIOL	Using Project-Based Learning to implement undergraduate research experiences.
Brenda Blacklock, CCB	A Case Study Approach to Developing Scientific Communication Skills in Senior Undergraduates
Snehasis Mukhopadhyay, CIS	Peer Assistant Role Models in a Graduate Computer Science Course
	Open Discussion

Part VI: The Record

There are currently 4 experiences approved for the Record:
Principles of Hydrology/Surface Water Hydrology (GEOL-G 430/G550)

Laboratory Assistantship in Earth Sciences
Learning Assistant for B110 Introduction to Psychology
Internship in Science-Based Field (SCI-I 494)

Last year we set a goal of increasing the number of experiences on the record. Unfortunately, we did not achieve this goal. The faculty and staff in the school have been strained by the additional work COVID has brought in addition to significant number of staff and faculty resignations. We will work to address that this next academic year.

Part VII: Graduate Program Assessment

1. Program Overview: Graduate programs at the Ph.D. and M.S. level are advanced fields of study that provide new knowledge in areas unique to the specialization of particular faculty members within research disciplines. At the graduate level overall, however, there are generally similar educational outcomes that are usually independent of the specific field of scientific study. IUPUI has a series of Principles of Graduate Learning (PGLs) that form a conceptual framework that describes expectations of all graduate/professional students at IUPUI. Virtually all graduate students in almost all disciplines are assessed on:

(a) Ability to undertake appropriate research, scholarly or creative endeavors, and contribute to their discipline;
(b) Demonstrating mastery of the knowledge and skills in an advanced area expected for the degree and for professionalism and success in the field;
(c) Thinking critically, applying good judgment in professional and personal situations;
(d) Behaving in an ethical way both professionally and personally";
(e) Ability to teach, often at the undergraduate level;
(f) Communicating effectively to others in the field and to the general public; and
(g) Success in finding employment in a field related to their graduate work.

Together, these PGLs are expectations that identify knowledge, skills, and abilities graduates will have demonstrated upon completing their specific degrees.

2. Program Outcomes: In general, graduate programs in the School of Science assess M.S. and Ph.D. students through comprehensive written and/or oral examinations by a committee related to their field of study, and regular committee meetings to discuss research progress and mastery of skills and knowledge. Their record of presentations at meetings, invited talks, publication and submission for grants or fellowships is also a means of assessment, and contributions to the scholarly literature both during and several years immediately after graduation similarly have are used as a form of program assessment.

Evaluation of these undertakings by the committees of graduate faculty remains the ultimate assessment standard of student success at the graduate level. These metrics are generally found to be an academically acceptable method of capturing most of the information necessary for graduate student assessment. In terms of actual numbers, approximately 125 students earned the M.S or Ph.D. in the School of Science in 2020-2021.

Part VIII: Assessment Plans for 2022

There are several large assessment efforts currently going on in the school. First, we will continue to complete the dossiers to reapprove the general education courses located within science. The campus is starting the 5-year cycle so we will be having multiple courses go through the review process for the second time.

The other formal assessment effort, going on in the school, is the departmental or program review. Math and Psychology were reviewed in Fall 2021 and Biology and Chemistry will be reviewed in Spring 2022. Following that Earth Science and Physics in Fall 2022; Computer Science and Neuroscience in Spring 2023; and Forensic and Investigative Sciences in Fall 2023.

Finally, many general education courses at IUPUI suffer from challenging DFW rates and this issue was particularly problematic for our service math courses during the covid pandemic. Science is committing time and resources to address this problem with the math department. First, we are in the process of hiring a post-doc (shared position with SIERI) who will be tasked with examining this issue, examining trends across time and identify potential solutions. In addition, we are in the process of creating a taskforce of various constituents across campus to also address this issue.

Appendix.

Preliminary efforts to evaluate an initiative introducing computation across the undergraduate physics curriculum

A. Gavrin and Gautam Vemuri

Department of Physics, Indiana University Purdue University Indianapolis,
402 N. Blackford St. LD154, Indianapolis, IN, 46202

Danka Maric

STEM Education and Innovation Research Institute, Indiana University Purdue University Indianapolis,
755 W. Michigan St. UL1123, Indianapolis, IN, 46202

We report our preliminary efforts to evaluate a departmental project: the inclusion of computational methods across our undergraduate curriculum. Our overarching goal is for students to consider computational approaches as a "normal" way to solve physics problems, on par with analytical approaches. In this paper, we focus on our efforts to evaluate the development of our students' attitudes and self-efficacy with respect to key computational methods. We describe our efforts to develop and deploy a survey instrument students complete each semester. This allows us to study, e.g., the points in the curriculum at which students gain confidence with particular methods, or adopt more expert-like attitudes regarding computation in general. We investigated the reliability of our instrument using a split-half process and found the Spearman-Brown coefficients for unequal length were r =0.818, r =0.895, and r =0.917 for the three constructs in our survey. We also provide preliminary data from the early use of the survey and outline next steps for the project.

I. INTRODUCTION

Over the last 20 years, much has been written about the need to incorporate computational methods in the undergraduate physics curriculum [1–7]. More recently, the importance of inculcating computational methods has been recognized at the national level. In 2016, the American Association of Physics Teachers (AAPT) released *Recommendations for Computational Physics in the Undergraduate Physics Curriculum* [8] and the APS-AAPT Joint Task Force on Undergraduate Physics Programs released its final report, emphasizing the importance of computation as a career skill for physics majors [9].

Despite this attention, only a few physics departments have embraced computational methods at the level we envision; Oregon State University [10] and Lawrence University [11] are notable examples. We were also surprised by the apparent lack of published instruments suited to evaluating the inclusion of computation in the curriculum. The PICUP project site [12] does not include any such tools, nor does PhysPort [13]. Indeed, Caballero notes that there is an opportunity for physics education researchers to support computational instruction through the development of computational assessments [7]. It is this lack of assessment instruments we are beginning to address. Our plan is to develop two instruments. The first is focused on students' attitudes and self-efficacy regarding computational methods. That instrument is the subject of this paper. The second will focus on students' abilities to use computational methods. Those interested in the first instrument may contact the authors for access to the current version.

To help readers understand the scope and constraints on our efforts, we briefly describe our institutional context and the broad outlines of our computational project in Section II. The remainder of the paper will focus on our preliminary efforts to evaluate our results. Section III will outline the methods we used to develop the first of two planned instruments, including efforts to establish validity and reliability. In sections IV and V, we will present and discuss preliminary data gained from this instrument, and Section VI will provide a summary and outline our plans for the future.

II. CONTEXT

A. Institutional context

This work was completed at Indiana University Purdue University Indianapolis (IUPUI), an urban, public university located in downtown Indianapolis, IN. The department is of moderate size: we have 10 tenured or tenure-track faculty members, and three full-time lecturers. We offer B.S., M.S., and Ph.D. degrees.

Our undergraduate curriculum follows a traditional model, including a two-course introductory sequence, a "modern physics" course, two upper-level labs, and single semester treatments of intermediate mechanics, electrodynamics, physical optics, quantum mechanics, and statistical physics. We also require a single semester of facultymentored undergraduate research as a capstone.

B. The computational initiative

Beginning in 2016, the faculty began discussing efforts to incorporate computational methods in the curriculum. From the outset, our overarching goal has been that our graduates will consider computational approaches to be a "normal" way to do physics. They should not consider the use of computation to be an unusual technique set aside for "special" problems, e.g. many-body physics. The initiative arose as a "grassroots" effort, but was supported from the outset by the department chair (one of the co-authors of this paper) and the college administration.

We gained initial support in the form of an internal grant from a campus center, IUPUI's STEM Education and Innovation Research Institute (SEIRI), supplemented by departmental funds. SEIRI also provided the support of a postdoc with evaluation experience to help us begin the effort reported here. The grant was supplemented by department funds used to support faculty travel to workshops hosted by the Partnership for the Integration of Computation into Undergraduate Physics (PICUP) [12], and to invite colloquium speakers who had experience teaching computational physics in a variety of contexts.

The first year of the project was devoted to expanding our overarching goal into specific student learning outcomes (SLOs), and to further establishing priorities, methods, and responsibilities. We discussed issues such as whether a specialized computational physics course (or sequence) should be developed, what skills and attitudes students should gain, what, if any, computational platform should be preferred, and how to assess the results. Some key conclusions were

1. We would incorporate computation in *all* courses.
2. Our primary focus must stay on physics, not coding.
3. Five SLOs describing skills and attitudes, e.g., students should not be satisfied with working code, but should use that code to "explore the physics."
4. A list of topics with which students should gain some fluency, e.g., numerical integration, data analysis, and using common tools such as Excel and MATLAB
5. That we would need to develop at least two instruments to evaluate the progress of the initiative.

C. Evaluation goals

The balance of this paper focuses on the first of two instruments conceived in item 5, above. Our approach to evaluating our "normalizing" goal is to understand the path students take in gaining confidence and skill with computational approaches. Discussions among the faculty led to a plan to use a repeated survey technique that allows us to understand that path, both at the individual student level and in aggregate.

The instrument was developed to address three primary constructs:

- Affect regarding the value of computational methods
- Self-efficacy regarding 10 computational methods
- Students' estimates of their *initial ability* on these same 10 methods

The survey was given to all students in physics majors' courses at the end of the semester from Fall 2018 through Spring 2021. The instructions specify that students should complete the survey after each semester during which they take one or more physics courses. Using this instrument, we hope to be able to answer research questions such as "Do our graduating students have expert-like attitudes regarding the use of computational methods?"; "At what points in the curriculum do their attitudes shift from naive towards expert?"; and similar questions focused on self-efficacy regarding particular skills.

III. METHODS

A. Instrument development

The development, review, and refinement of the present instrument took place in three stages. First, initial items were developed by project leaders and further discussed and adjusted by the full group of faculty members in physics. We worked until a consensus was reached that the instrument could be used as an effective evaluation tool. The instrument begins with demographic questions (names, student IDs, physics courses taken that semester). These are followed by items asking students to rate their agreement with statements related to computational physics, e.g., “Using computational methods helps me understand physics topics” (fivepoint Likert scale). Students are then asked to rate both their present and initial abilities on ten computational skills, e.g., numerical integration, on a 1-10 scale (initial is defined as “at the time they began the program”). During the second stage of development, the instrument was reviewed by an evaluation expert with instrument development experience at SEIRI, which resulted in a few items being reworded for better clarity. This form of the instrument was used for 4 semesters of data collection during the period of internal funding.

B. Validity and reliability

We sought preliminary evidence of content validity after receiving further funding from NSF. Content validity evidence involves examining the relationship between the instrument content (e.g., themes, wording, item format, tasks, or questions) and the construct it is intending to measure through evaluations from expert judges, among other methods [14].
We asked five content area experts from PICUP to provide feedback on the overall structure of the instrument, as well its clarity and completeness. There was agreement among the experts that the items are examining what they are intended to examine—students’ attitudes and self-efficacy concerning computational methods. Some clarifications and additional items were also suggested. For instance, several of the content experts agreed that the term “analytical methods” might be confusing, particularly to beginning students. The phrase “pencil and paper math” was added as a parenthetical explanation. One item was dropped and four new items were added, bringing the total number of items in this section from six to nine. Finally, the order of the items asking students to rate their skills was changed such that present skills were rated before initial skills. This updated version was used in the two most recent semesters of data collection.
We did not have data from the same participants on multiple occasions and thus were unable to examine test-retest reliability. However, we were able to estimate internal consistency by obtaining split-half correlation coefficients. This method examines the agreement between different parts of a measure by splitting scores into two halves and examining the corrected correlation between the two halves, which serves as an estimate of the reliability of the full-length measure [14]. Split-half correlations were respectively examined for the affective, present skills, and initial skills item clusters. We used an odd-even split, in which odd-numbered items are in one subset and even-numbered items are in the other. This type of split avoids any factors related to item order (e.g., participant fatigue) from having an extraneous effect on the coefficient by ensuring items from each portion of the measure are represented in each subset [15].
The Spearman-Brown coefficients for unequal length were $r = 0.814$ for the affect questions, $r = 0.895$ for the present skills items and $r = 0.917$ for initial skills items in the updated instrument.

Although there is debate on this topic, high Spearman-Brown coefficients are thought to reflect better reliability, with some experts citing reliability coefficients of 0.7 to 0.8 or above being acceptable for research purposes [16]. Based on these guidelines, the current instrument seems to have reasonable internal consistency.

We should note that the value $r = 0.814$ above was obtained for the most current version of the survey, used for two semesters, with $N = 130$ respondents. The self-efficacy construct was unchanged between versions, and had $N = 323$ respondents. For completeness, we also performed a splithalf analysis of the affect questions on the earlier version of the survey, and found results that were consistent $r = 0.866$.

C. Data analysis

The first section of the survey measures students' attitudes towards computational methods. Our approach is to begin with a one-way ANOVA followed by Tukey's HSD (honestly significant difference) test [17]. In each case, we compare all records from students who are completing a 100 level course, 200 level course, etc. If a student takes courses at multiple levels in a given semester, we consider the highest level course taken. In some cases, our results violated the assumption of equal variances between groups. One-way ANOVAs are typically quite robust [17] but since we have unequal group sizes, this violation can be problematic. For the questions that violated this assumption, we applied a Welch correction [18]. For the follow-up test to the Welch corrected ANOVA, we used the Games-Howell test [19], which is designed for assumption violations but functions similarly to Tukey's HSD in that it produces results for all pairwise combinations of treatments (courses levels). Where we report results that are statistically significant ($p < 0.05$), we also report effect sizes using Hedge's g, a measure similar to Cohen's d, but suited to cases with different sample sizes [20].

D. Initial use

Each semester, about 2 weeks before final exams, a link to the survey is sent to all students who are completing the targeted courses. The instructions tell students that they will be asked to complete the survey each semester, but that only one copy is necessary if they are taking more than one physics course. Participation is voluntary, and no incentives were offered for participation.

This design allows us to measure the changes in students' attitudes over time, both in the aggregate and as individuals. Our response rates are reasonable, typically near 20%. We note that selection effects may bias results, and that the sample size in upper level classes is low due to the size of our major. As a result, we cannot yet observe statistically significant results tracking individuals or single courses. Our present data set allows us to find significant results when we aggregate responses over students completing courses at the 100 level, 200 level, etc. (This roughly tracks students' 1st year classes, 2nd year, etc). We report those results, based on 6 semesters: Fall 2018 - 2020, and Spring 2019 - 2021. The results are described in the next section.

IV. RESULTS

A. Attitudes

For this work, we analyzed the five affect questions that were included in both the original and updated surveys. All five produce statistically significant results in the ANOVA, and most produce multiple significant results in the Tukey HSD. As an example, we highlight this item "Computational methods, experiments, and analytical solutions are equally necessary in the field of physics," phrased as 5-point Likert scale. For convenience, we will refer to this item as "item A1" (Affect 1).

TABLE I. Significance and effect size for pairwise comparisons among course levels for item A1, organized by course level.

Course levels compared	p	g
100, 300	0.015	0.62
100, 400	0.040	0.74
200, 300	0.014	0.77
200, 400	0.036	0.91

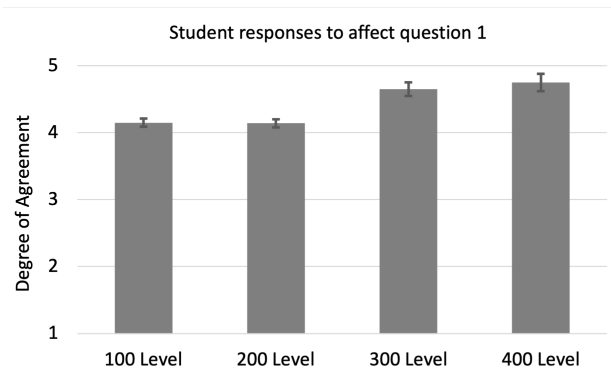

FIG. 1. Students' average responses to item A1 grouped by highest completed course level. Error bars are standard errors.

The omnibus one-way ANOVA showed a significant difference between class levels, $F(3,340) = 4.57, p = 0.001$. The Tukey HSD follow-up showed significant pairwise differences in four of the 6 possible pairwise comparisons. The results are detailed in Table I. The data is also illustrated in Fig. 1. The numbers of respondents are $N_{100} = 183, N_{200} = 132, N_{300} = 23, N_{400} = 12$.

B. Competencies

The second portion of the survey asks students to rate their present ability on a scale of 1 to 10 for ten computational skills. Eight of the ten produce statistically significant results in the ANOVA, and most produce multiple significant results in the TukeyHSD. We highlight two of these competencies here: use of MATLAB, and matrix operations. We respectively designate these items "SE1" and "SE2" (self-efficacy 1 and 2). For item SE1, the omnibus one-way ANOVA results were Welch's $F(3,40.750) = 22.658, p < 0.01$. For item SE2, we find

$F(3,41.465) = 11.098, p < 0.01$. As above, the results for all statistically significant pairwise comparisons are summarized in Table II. The data is shown in Fig. 2. The numbers of respondents to these questions were $N_{100} = 166, N_{200} = 128, N_{300} = 21, N_{400} = 12$.

TABLE II. Significance and effect size for pairwise comparisons among course levels for items SE1 and SE2

		MATLAB
Course levels compared	*p*	*g*
100, 200	< 0.01	0.59
100, 300	< 0.01	1.04
100, 400	< 0.01	1.35
200, 400	< 0.01	0.85
		Matrix Operations
Course levels compared	*p*	*g*
100, 300	< 0.01	0.82
100, 400	0.029	0.70
200, 300	< 0.01	0.69

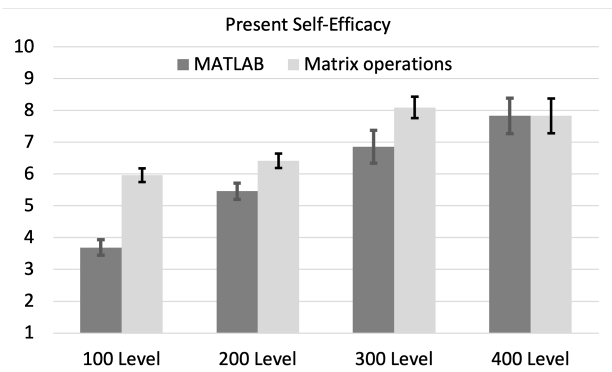

FIG. 2. Students' responses to items SE1 and SE2 grouped by highest completed course level. Error bars are standard errors.

V. DISCUSSION

To date, our results suggest that our instrument is valid and reliable at a basic level. After several stages of review and adjustment, faculty within and beyond the department agree that the items are clear and focused on the desired constructs indicating content validity. The split-half correlation coefficients we obtained for each construct were over 0.8, indicating reasonable internal consistency. We will continue our efforts to establish validity and reliability in coming semesters.

The data presented above enables us to begin to address our stated goal of understanding the path along which our students develop the desired computational skills and attitudes. Interpreting Hedge's g values is similar to Cohen's d, with most guidance characterizing $g = 0.5$ as a medium effect, and $g \geq 0.8$ as a large effect [20]. By this standard, all three examples described here, plus many others in our data, show students making medium or large gains in adopting expertlike attitudes and in increasing self-efficacy.

One notable observation is that some skills and attitudes appear to develop in a stepwise fashion between the 200 and 300 level. Results for item A1 presented in Table I and Fig. 1 develop this way. Likewise, the second table and figure show that students' self-efficacy with respect to matrix operations (item SE2) also takes a substantial jump at this level. In contrast, students' self-efficacy with respect to using MATLAB (item SE1) develops more steadily, as shown in Table II and Fig. 2. We see these trends in other questions not presented here as well.

As we gather more data, we expect that this trend will sharpen, and we will be able to investigate which courses at each level are most responsible for these improvements. This observation highlights one of the chief benefits this instrument offers. It allows us to determine where in the curriculum students' gains are occuring, and to compare those gains to the goals of the courses taken. If some courses seem to underperform, corrective action can be considered. Similarly, if certain courses produce large gains, it may be possible to adopt the methods used in those classes to improve others.

VI. CONCLUSION

Our efforts are still at an early stage, but our results thus far point towards some preliminary conclusions. We have developed an instrument intended to measure students' attitudes and self-efficacy towards computation, and we have established content validity by involving experts in several rounds of review of the instrument. Regarding reliability, we have thus far established internal consistency by measuring splithalf correlation coefficients. Over several semesters use of the instrument, we find that our students' attitudes become more expert-like as they progress through the curriculum, and that their confidence with using computational methods also grows, with effect sizes that are in many cases substantial. We note that some of the measures we focus on grow steadily, while others seem to take a particularly large step between the 200 and 300 level. We speculate that this is a result of the significant step up in sophistication in our classes and decrease in class size at that level.
As we continue to acquire data, we will soon be able to look more closely at these developmental processes, identifying the particular courses in which students make progress on specific survey items. Additional data will also allow us to more fully establish validity and reliability. Factor analysis will allow us to examine the instrument structure, and correlating results from this instrument with data on student performance in courses will help establish predictive validity.

ACKNOWLEDGMENTS

The authors acknowledge financial support from IUPUI's STEM Education and Innovation Research Institute (SEIRI) and from National Science Foundation grant DUE-2021209. We also wish to thank the Partnership for Integration of Computation into Undergraduate Physics (PICUP).

[1] H. Gould and J. Tobochnik, Integrating computation into the physics curriculum, in *Computational Science — ICCS 2001*, edited by V. N. Alexandrov, et al. (Springer-Verlag, Berlin/Heidelberg, 2001).
[2] R. Landau, Variation of instructor-student interactions in an introductory interactive physics course, Comput. in Sci. and Eng. 8, 22 (2006).
[3] J. R. Taylor and B. A. King, Using computational methods to reinvigorate an undergraduate physics curriculum, Comput. in Sci. and Eng. 8, 38 (2006).
[4] R. S. Chabay and B. A. Sherwood, Computational physics in the introductory calculus-based course, Am. J. Phys. 76, 307 (2008).
[5] N. Chonacky and D. Winch, Integrating computation into the undergraduate curriculum: A vision and guidelines for future developments, Am. J. Phys. 76, 327 (2008).
[6] R. M. Serbanescu, P. J. Kushner, and S. Stanley, Putting computation on a par with experiments and theory in the undergraduate physics curriculum, Am. J. Phys. 79, 919 (2011).
[7] M. D. Caballero and L. Merner, Prevalence and nature of computational instruction in undergraduate physics programs across the United States, Phys. Rev. Phys. Educ. Res. 14, 020129 (2018).
[8] AAPT recommendations for computational physics in the undergraduate physics curriculum, https://www.aapt.org/Resources/upload/AAPT_UCTF_CompPhysReport_final_B. pdf (2016), retrieved 5/16/21.
[9] P. Heron and L. McNeil, *PHYS21: Preparing Physics Students for 21st Century Careers* (American Physical Society, College Park, MD, 2016).
[10] D. H. McIntyre, J. Tate, and C. A. Manogue, Integrating computational activities into the upper-level Paradigms in Physics curriculum at Oregon State University, Am. J. Phys. 76, 340 (2008).
[11] D. M. Cook, Computation in the Lawrence physics curriculum, https://www2.lawrence.edu/dept/physics/ccli/compatlu.pdf (2006), retrieved 5/16/21.
[12] Partnership for the Integration of Computation into Undergraduate Physics, https://www.compadre.org/picup/, retrieved 5/25/21.
[13] PhysPort, https://www.physport.org/, retrieved 6/1/21.
[14] *Standards for Educational and Psychological Testing* (American Educational Research Association, 2014).
[15] R. F. DeVellis, *Scale Development: Theory and Applications* (Sage Publications, Newbury Park, CA, 2017).
[16] R. M. Furr, Split-half reliability, in *Encyclopedia of Research Design*, edited by Salkind, Neil J. (Sage Publications, Newbury Park, CA, 2012).
[17] D. C. Howell, *Statistical Methods for Psychology* (Cengage Learning, Independence, KY, 2007) pp. 316–318, 370–372.
[18] B. L. Welch, On the comparison of several mean values: An alternative approach, Biometrika 38, 330 (1951).
[19] P. A. Games and J. F. Howell, Pairwise multiple comparison procedures with unequal n's and/or variances: A monte carlo study, J. of Educ. Stat. 1, 113 (1976).
[20] C. O. Fritz, P. E. Morris, and J. J. Richler, Effect size estimates: Current use, calculations, and interpretation, J. Exp. Psychol. Gen. 141, 2 (2012).