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RESEARCH ARTICLE:

Integrating Research-Based Learning into the Undergraduate Curriculum: Challenges and Solutions

Teresa Eaton[1], Noel Richardson[2] and Rachael Schmidt[3]

Abstract

Integrating undergraduate research into introductory level courses can improve student accessibility, inclusion, and retention. Herein, we discuss two one-on-one research projects that are being scaffolded into the undergraduate curriculum. We will describe the design and application of CUREs (course-based undergraduate research experiences) in forensic biology as well as physics and astronomy degree programmes. The forensic biology CURE includes trace evidence analysis and models the experimental methods, techniques, and instrumentation students will use in their future careers. In the Eclipsing Binaries CURE, students are introduced to coding and computational physics through modelling spectroscopic and photometric data. The lessons learned through scaling up these interdisciplinary models can apply to other fields of study.

Keywords: *CURE challenges and solutions; scaffolding research into curriculum; undergraduate research; research-based learning; astronomy*

Introduction

Undergraduate research is frequently required for admission and success in graduate programmes, but those experiences may not be accessible to all students. Some professors often lack the resources and institutional support to design and facilitate research experiences for undergraduates. Including course-based undergraduate research experiences (CUREs) in the core curriculum can include all students in undergraduate research. Undergraduate research has many clear benefits for students including improving student retention as well as increasing interest and success in graduate schools (Laursen *et al.,* 2010: 28; Eagan *et al.,* 2010: 686; Seymour *et al.,* 2004: 497; Russell, Hancock and McMullough, 2007: 548). Developing and implementing course-based undergraduate research activities can eliminate socio-economic and cultural barriers preventing students from obtaining research experience (Estrada *et al*., 2016: 2; Eagan *et al*., 2011: 2).

Many factors can prevent students from pursuing undergraduate research. Students at community colleges or teaching institutions may be unaware that research opportunities exist (Spronken-Smith, Mirosa and Darrow, 2014: 357). Students, particularly first-generation college attendees, are uninformed of the benefits, often do not know how to get involved, and often lack the cultural capital to pursue research experiences (Bourdieu, 19[4]86: 247). In addition, students with parents that are unfamiliar with academia may view research as a distraction, separate from coursework. To further complicate these barriers, undergraduate research experiences are often unpaid. Students from low-income families may have conflicting obligations outside their studies, including working or caring

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[1] Embry-Riddle Aeronautical University, eatont2@erau.edu
[2] Embry-Riddle Aeronautical University, richan11@erau.edu
[3] Embry-Riddle Aeronautical University, schmir11@erau.edu

for family members. They may not have the time or the financial security to pursue an unpaid research opportunity (Intermann, 2009: 261).

In addition, participating in undergraduate research has complicated social norms that can be difficult to navigate. Relationships between students and professors are built through informal social interactions. Students may not know how to find a faculty mentor, or if it is culturally acceptable to reach out to a faculty member. Students may be apprehensive of pursuing research opportunities unless they know researchers within their community. Unless mentors introduce the idea of research, students may not consider it as an option to enhance their college experience. Many students lack confidence and view STEM faculty as unapproachable or intimidating (Healey *et al.,* 2010: 237). Students from upper-class families or those who have parents that attended college are more likely to work with professors for research credit, as well as reach out to a faculty in person or by e-mail (Kim and Sax, 2009: 441; Res. High Educ., 50: 437-459). In addition, gender and racial differences can play a role. Female and minority students may be hesitant regarding their ability to apply for independent research opportunities (Hernandez *et al.,* 2013: 92). Societal bias for hiring also applies to selection for academic research. Males are more likely to be hired. They are also paid more than females (Moss-Racusin *et al*., 2012: 16476). White students are also more likely to be selected (Milkman, Akinola and Chugh, 2014: 3). This creates an uphill battle for underrepresented groups, because graduate schools often prefer or require several years of undergraduate research, especially as subject tests for the GRE are dropped from consideration, because they show little correlation with postgraduate success (Levesque *et al*., 2015: 9).

Several factors can impact faculty selection of students as well as create barriers for professors to include undergraduates in research projects. Conflicting demands on principal investigators, including the pressure to publish in high-impact journals can exacerbate student inequity. In addition, mentoring undergraduates to perform research can be time consuming and costly. Training undergraduates can misalign with the university's mission of creating novel results and contributing to the expansion of knowledge. Training the next generation of scientists is often secondary. This requires high-quality research that can be difficult to accomplish while simultaneously training undergraduates.

Faculty preference for the "best" students can further deepen inequality. Mentorship is required in faculty positions; however, success is often measured by how well the mentees do in their future careers. Assessing the success of mentorship only by the final product and not from the experience and value added to the student's education pressures faculties to select students who will later have successful careers. This can include students who have previous research experience. If faculties use grade point average (GPA) as a metric for selecting undergraduate researchers, then only the highest performers are selected. These metrics do not necessarily predict the students' ability to do undergraduate research. Students with ambition, scholastic achievement, and career orientation are often selected, further perpetuating inequities. This eliminates the possibility of faculties involving students with less academic preparedness, cultural backgrounds that do not emphasize research, shy or modest students, or students who are not the top academic performers.

There is a cure for inequality in undergraduate research. Instead of requiring of students to apply for or seek out undergraduate research opportunities, research can be introduced into a course that students are required to take for their majors. Authentic research experiences can thus be included in the required curriculum. Course-based undergraduate research experiences (CUREs) can include all students rather than a select few. CUREs can have the five elements of essential research: 1) engaging students in scientific inquiry; 2) encouraging collaboration; 3) examining relevant topics;

4) exploring scientific questions with unknown answers; and 5) building scientific knowledge (Auchincloss *et al*., 2014: 37).

To maximize the benefits for students, CUREs need to be implemented as early as possible. Introducing research to first- or second-year students can eliminate inequities by engaging all students in authentic, undergraduate research early in their academic careers. Courses with CUREs can be required for their degrees and provide course credits. This saves students time, because they will not have to volunteer for a research position but can still have the benefits of the experience for their future careers. CURE instructors will receive teaching credit for mentoring undergraduates, saving faculty time and resources. The pressure for principal investigators to publish will be lessened, as the main goal is the education of the students. This provides a level playing field for all students by providing equal opportunities for research experience.

Through CURE implementation, principal investigators have more than GPA to predict student success. CURE courses could highlight students with excellent research skills, such as programming or technical ability, that are not reflected in the students' GPA. CUREs teach students scientific skills and prepare them to be more effective in the research process. For institutions that do not offer undergraduate research, CUREs may be the only relevant experience students have to include in graduate school applications, especially when programmes such as the NSF (National Science Foundation) Research Experiences for Undergraduates (REUs) are extremely competitive (Chicago Materials Research Center, 2022). For example, Georgia State University, a large research institution, received over 200 applications for 8–12 available positions in the Physics and Astronomy REU programme (D.M. Crenshaw, personal communication).

CURE Design

There are several ways to design a CURE that aligns with institutional, departmental, faculty, and student needs. The first step is deciding on a research project. This may be similar to a faculty's research or follow an existing model. The CURE could include a single class meeting or an entire semester. Students can write their experimental design or protocol, or it may be provided to them by their instructor. An assessment component must also be introduced. A scaffolded approach to designing a CURE can be found in Table 1.

Table 1: Timeline for CURE development

Before the course	**During course**	**After course**
1. Test proof of research concept through one-on-one student research (optional) 2. Go to CUREnet (https://serc.carleton.edu/curenet/index.html) for resources 3. Prepare materials 4. Conduct pre-assessment	1. Students write an experimental protocol with their instructor 2. Students perform experiments 3. Troubleshooting and reiteration	1. Follow up with students 2. Compile student data 3. Conduct post-assessment

Identifying a research topic when designing a CURE can be challenging (Govindan, Pickett and Riggs, 2020). Faculty can be apprehensive about designing course-based undergraduate projects due to location and time constraints. Fortunately, CUREs have become increasingly common and there are many institutions and professional organizations to offer support. Networking within these groups can provide valuable information and mentorship. Several large institutions have implemented undergraduate research into introductory courses, including the Freshman Research Initiative (FRI) at UT at Austin, the First-year Innovation and Research Experience (FIRE) at the University of Maryland, and the Place-Based Learning Communities (PBLC) at Cal Poly Humboldt State University (Simmons, 2014: 93.1; Killon and Page, 2016: 47; Trencher *et al*., 2014: 153).

Another way to introduce authentic undergraduate research is to join a network model. In a network model, students become part of a larger, multi-institution team answering a shared question. Some examples include BASIL (Biochemistry Authentic Scientific Inquiry Laboratory), SEA-PHAGES (Science Education Alliance-Phage Hunters Advancing Genomics and Evolutionary Science), the Great Sunflower Project, and the Small World Initiative (Irby *et al*., 2018: 480; Hanauer *et al*., 2017: 13533; Oberhauser and LeBuhn, 2012: 318; Barral *et al*., 2014: 627). Using this method, the protocols and course procedures have already been developed. Students crowdsource data collection for a national repository (Hanauer *et al*., 2017: 13533; Oberhauser and LeBuhn, 2012: 318; Barral *et al*., 2014: 627; Reeves *et al*., 2018).

A different method includes introducing a CURE project that aligns with the faculty research area. This provides the students with "hands-on" training for their specific research interests. In this model, students may answer a shared question using different approaches. Aligning a CURE with faculty research interests may be the approach that aligns the most closely with the research community. Students can appear in publications and present original work at conference meetings.

A student-centred inquiry style CURE allows students to develop research questions under the supervision of faculty and teaching assistants (Govindan *et al*., 2020). Students will need to perform a literature review and brainstorm a topic. This may be difficult at the introductory level because projects may need students to rely on background knowledge that they do not yet have. Allowing students to develop their questions will give them personal relevance and ownership over their research design. During the course, students gain valuable real-world research experience through collaboration, iteration, discovery, and troubleshooting (Corwin *et al*., 2018: 2) To increase collaboration, students can share data and monitor one another's work. The longer students are engaged in CURES and the research process, the more likely they are to pursue research or continue a research-related career path (Hidi and Renninger, 2006: 111). If adding a full CURE course is not feasible, an inquiry-based laboratory activity can be introduced into an existing course. This approach does not require a full course revision. An existing laboratory can be modified to include a research component that has no clearly defined "correct" answer, also known as an open-ended, inquiry-based activity.

After the course is completed, students can compile data and demonstrate mastery of the course objectives. To introduce an assessment component to a CURE, the course learning objectives may need to be modified to suit a research model. Course goals and outcomes may differ, depending on discipline; as a result, there is no "one-size-fits-all" assessment. For example, in biology or chemistry, the course learning objectives may be instrument proficiency, proper laboratory techniques, or record-keeping protocols. In physics or astronomy, the learning objectives may be the ability to write code or determine the quality of scientific studies. Some broad learning objectives that are relevant across disciplines include scientific literacy, scientific communication, error determination, and experimental design (Shortlidge and Brownell, 2016: 400). CURE assessment can include a presentation, proficiency demonstration, writing standard operating procedures, or completing open-ended essay questions.

Here, we describe two interdisciplinary projects at our institution to include research in our undergraduate curriculum.

Project 1: Forensic Trace Evidence CURE

In the forensic biology undergraduate degree programme, many students plan to become forensic scientists or laboratory technicians. When two items come into contact, there is an exchange of microscopic, or trace material (Mistek *et al.,* 2019: 642). A project analysing trace evidence was chosen to give students hands-on experience in handing and analysing small amounts of material. Students use instrumentation and techniques identical to those they will use in their future careers or graduate school. The cosmetics as trace evidence project began as a one-on-one undergraduate research project funded through a small institutional grant. This project was successful on a smaller scale, with simple protocols and minimal costs. As a result, it was well suited for integration into existing laboratory courses. We were able to use existing equipment and resources in the chemistry and engineering teaching laboratories, including samples, supplies, reagents, and instrumentation.

During the CURE, students developed skills in proper sample handling, record keeping, and data collection. Contamination of samples would convolute the statistical analysis; therefore, they must clean the instruments and work area thoroughly between samples. Students are also trained to be mindful of safety, and immediately stop work if something seems potentially dangerous. In addition to traditional course skills, they learn literature review, method design, troubleshooting, and research best practices. The exchange of trace evidence can be used to develop a connection between a suspect and a victim or crime scene. Trace evidence can include cosmetics, pollen, fibres, hair, gunshot residue, or bodily fluids. Analysing several types of evidence from a crime scene allows forensic investigators to develop a complete picture of a crime. As individuals become increasingly aware of DNA and fingerprinting, forensic scientists must find new types of evidence to examine.

There are government and private forensic databases for trace evidence, but the investigation of cosmetics is underexplored due to the lack of national and international standards (Mistek *et al*. 2019: 642). Cosmetic evidence is gaining popularity because it is easily transferred between suspects, victims, and their surroundings. For example, lipstick smears can be collected from drinking glasses, cigarette butts, paper, and other surfaces. The composition and physical appearance of cosmetics vary between manufacturers. The project goal was to develop a predictive model to distinguish between cosmetic brands and types using chemical and morphological features. Trace amounts of lipsticks, eyeshadows, bronzers, and highlighters undergo instrumental analysis and statistical modelling. Optical and scanning electron microscopy (SEM) can be used to distinguish morphological features including particle size, shape, and colour. Energy dispersive spectroscopy (EDS) is used to provide the relative ratios of elements in each sample (Najjar and Bridge, 2020: 2). Fourier transform infrared (FTIR) spectroscopy is used to establish a spectral fingerprint for each cosmetic sample (Sharma, Bhardwaj and Kumar, 2019: 88). Samples are differentiated by examining the presence or absence of peaks which represent different chemical constituents (Mistek *et al*., 2019: 642). In future, this model can be a tool to help investigations prosecute criminals and exonerate innocent people who have been wrongfully charged (Chophi *et al*., 2019).

Scanning electron microscopy (SEM) provides a detailed image of the sample by bombarding the surface with a beam of electrons. The resolution of an electron microscope is about 100 000 times greater than a light microscope (Girão, Caputo and Ferro, 2017: 157). Energy dispersive spectroscopy (EDS) can be used to determine the elemental composition of a sample particle or an average in a particular area (Melquiades *et al*., 2015: 278). Electrons interact with the atoms in the sample, producing information about the topography and composition (Lin *et al*., 2015: 200). Each element has a unique spectral signature upon emission of light following excitation (Najjar and Bridge, 2020: 2). These spectral signatures can provide the relative elemental composition. Although it is difficult to determine the exact amount of each element in the sample without calibration, the ratio of elements is provided in percentages.

Fourier transform infrared spectroscopy (FTIR) is a form of vibrational spectroscopy that measures the absorption of infrared radiation. Each type of bond absorbs radiation at different frequencies, creating a unique spectral fingerprint for each sample. FTIR analysis is fast, non-destructive, and requires minimal amounts of sample. Data collected from FTIR can be used to determine composition using a digital library. The number, size, shape, and position of peaks can be used to distinguish between similar samples (Sharma *et al.*, 2019: 88). Once data have been collected, chemometric analysis is performed to distinguish, classify, and find patterns between samples (Kulikov *et al*. 2012: 413). Hierarchical cluster analysis (HCA), principal component analysis (PCA) linear discriminant analysis (LDA), and k-nearest neighbours (KNN) are performed using Statistical Package for the Social Sciences (SPSS). These methods can be used to develop a predictive model to determine unknown cosmetic brands and types (Adams, 2004: 117; Najjar and Bridge, 2018: 32).

The trace evidence research project was scaffolded into the laboratory curriculum of two courses in the undergraduate forensic biology degree programme, including Trace Evidence Laboratory and General Chemistry II Laboratory. The process for incorporating research is outlined in Figure 1. Before experiments were performed, students were given a week to plan their approach and write protocols. Before the first lab meeting, students were given a pre-test to establish base knowledge and provide an assessment of learning outcomes. During the first lab meeting, students were tasked with researching a method for collecting FTIR and SEM data and writing standard operating procedures. They are given a few research papers as a guide and encouraged to research more. After the students had agreed on an experimental protocol, they sent it to their instructor for review.

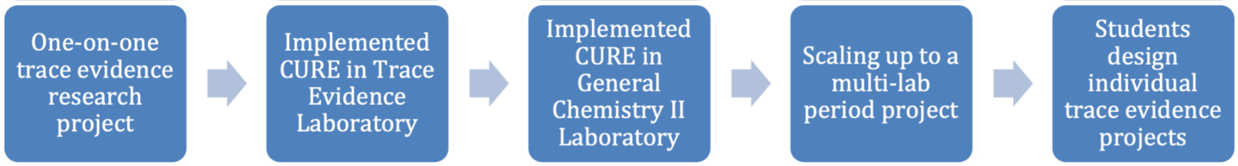

Figure 1: Scaffolding Trace Evidence Research Project into the Forensic Biology Undergraduate Curriculum

In the Fall of 2021, the trace evidence research project was first transitioned into a course called Trace Evidence Laboratory. This course is required for forensic biology majors and focuses on training forensic scientists to operate several instruments and utilize techniques they will use in their future careers. A group of five students worked together on the project in the final two weeks of the semester. Students were tasked with collecting FTIR and SEM data to provide discriminating peaks for statistical analysis. By incorporating the CURE laboratory experiments into an existing course, we were able to utilize institutional resources for research. These include instrumentation and supplies that are generally reserved for teaching laboratories. Rather than overhauling the entire course, the CURE was introduced as a project towards the end of the semester. Students were trained in laboratory techniques, the use of instruments, and data collection before performing the CURE.

In the Spring of 2022, the trace evidence research project was implemented in a first-year, second-semester general chemistry laboratory course. A traditional laboratory experiment was replaced with a modified protocol modelled after the trace evidence project. A total of 19 students worked in small groups of two to three. Each group received one cosmetic sample to analyse. Students were instructed to observe and record morphological features using optical microscopy and chemical composition data from FTIR. During the second laboratory meeting, students began data collection by performing FTIR on cosmetic samples. Five students split 30 samples among the small student groups. Small groups were chosen because the students can verify one another's work, ensuring good laboratory techniques. Students performed FTIR experiments for the remainder of the semester. Each sample had to be analysed several times and averaged.

After the students had finished the semester, the data were compiled for statistical analysis. A colleague in the social sciences used SPSS and student data to find discriminating features between cosmetics. Using this statistical model, it is possible to classify unknown cosmetic samples. A post-test was also implemented, showing that the students enjoyed the CURE; citing it provided them with a clearer picture of how research is performed. To introduce an assessment component, students compared their samples to previously analysed samples. Before the laboratory was performed, morphological features and FTIR spectra of several samples were provided, which included one "unknown" sample they were tasked with determining. Providing this data into the experiment design saved time and ensured students would understand the scope of the research. Upon completion, 17 of the 19 students identified their sample of interest positively by comparing it to the provided data. This type of laboratory deviates from a traditional CURE because it lacks open-ended inquiry.

There were several benefits of including CURE-based laboratory experiments in the curriculum. Students gained insight into the nature of research through iteration and open-ended inquiry. They were more likely to see the value in research and seek out similar opportunities. In addition, students were trained in instrumental analysis earlier. As a result, they will be more prepared for their upper-level courses. Students gained additional practice with instrumentation, increasing their proficiency. Students also learned process skills outside the scope of traditional laboratory experiments. Additionally, there were benefits for the faculty as well. More samples are analysed, contributing to the data sets that can be included in the statistical analysis. Ideally, the more data contributing to the statistical model, the more accurate and complete the database will be for determining unknown cosmetics. Training students in their laboratory courses also saved faculty time because all students in the forensic biology programme have the skills to continue this project on an individual basis.

Some issues arose during the first iterations of the CURE. The Trace Evidence Laboratory students took more FTIR readings than were necessary. This was caused by a miscommunication between students and instructors. Spectra are typically averaged in the instrument software. There is a setting to average multiple spectra without reloading samples. Students were unaware of this and instead took several replicates of spectra manually, reloading samples each time. In addition, students were inconsistent when labelling their samples in the saved data files. Compiling the data across different student groups was difficult. One mistake was assuming the students could develop data collection methods independently. To avoid these errors, a standard protocol could be provided to the students instead of allowing them to develop one independently. This may result in less student ownership over the work, but it will provide consistent parameters for future publication. These issues could have been avoided with more instructor supervision.

Another area for improvement includes introducing a new type of assessment that accommodates open-ended inquiry. When this research was introduced in the first year of the general chemistry course, the students reanalysed samples that had previously been run using FTIR. This was done so that the lab could have a clear solution that students could understand, by matching their unknown sample to a known solution. This is not typical for CUREs, because the purpose is to perform original work. The students could be introduced to the project using a more traditional laboratory. Then, in subsequent laboratory meetings, they can analyse new, unstudied samples. It may still be necessary to have the students match their unknown sample to a known sample first to familiarize them with discriminant analysis. This ensures that students understand the point of the research and are properly trained in sample handling, safety, and laboratory techniques before performing authentic research.

In future, students from the General Chemistry II laboratory and Trace Evidence Laboratory courses could collaborate on different aspects of this project. General Chemistry II students can learn the basics and perform FTIR. This will prepare them to take organic chemistry in year two. Trace

Evidence Laboratory students can obtain elemental analysis and morphological data from SEM/EDS. This aligns with the learning objectives of the course. The model of collecting repetitive data to build a database can be repeated with other types of trace evidence. This CURE could be a semester-long project where students choose their evidence of interest (hair, pollen, gunshot residue, soil, etc.). Data collected would be useful to the larger scientific community, particularly forensic sciences. Interdisciplinary collaboration is essential for success. Currently, our statistical analysis is performed by a colleague in the psychology department. In future, students from statistics or data analytics courses could perform the statistical analysis for course credit in an interdisciplinary CURE.

One way to improve assessment is to have the students write a mock manuscript or present their findings. After their experiments are complete, students would have the opportunity to apply their scientific writing and literacy skills. In addition to writing, their assessment could include a poster or group presentation. At the end of the semester, their work could be used to procure funding or submit for publication.

Project 2: Eclipsing Binaries CURE

One of the largest challenges in the education of physics and astronomy students is providing undergraduate students with the necessary skills to compete for both industry jobs and graduate school admissions while retaining the rigorous curriculum that is typical of a physics degree. In the last decade, the largest intersection of the industry and graduate school skill sets for the students has quickly become scripting with Python. Astronomy has benefited greatly from the user community of Python (Robitaille *et al*. 2013: 8), which allows students to build the necessary skills so that they can compete for both graduate schools and industry jobs in fields such as data science (VanderPlas 2016: 13) simultaneously upon completion of their degree.

This astronomy CURE uses eclipsing binaries as the primary way in which the methods of observing and analysis are taught. Eclipsing binaries are double stars that orbit each other and block light from each other during their orbit due to their geometric orientation. Within the CURE, students learn how to collect and handle astronomical data with observational laboratory exercises that focus on their successful collection of useful spectroscopies of an eclipsing system chosen by the instructor. This data collection takes at least half of the semester, while the students learn the foundations of data collection and analysis. In the second half of the semester, the students continue the project through the analysis of photometric satellite data on the same eclipsing binary system from NASA's *Transiting Exoplanet Survey Satellite* (*TESS)* (Ricker *et al*., 2015: 6). The students then learn more about the spectroscopy they collected through measuring radial velocities of the system and then solving the orbit using the current state of the art software PHOEBE (PHysics of Eclipsing BinariEs Modeling Software) (Prša *et al*., 2016: 6).

Astronomy students often benefit from formal and informal instruction at a telescope, with many colleges or universities in the United States having observatory access through either a partnership or on-campus facilities. Observatories not only provide a laboratory environment for astronomy students, but also provide a location for inspiring interest in science to both students and the public. For formal instruction at the telescope, most astronomy majors take a course about observational techniques for astronomy. This course is a laboratory course and lends itself well to designing a CURE.

To implement a CURE in this astronomy course, it is necessary to balance its placement in the curriculum with the skills needed for success, including Python scripting skills. In our programmes, first-year students enrol for an introductory computer science course focused on Python, along with computational methods in a physics course that teaches the techniques with Python. In parallel to the introductory physics sequence, there are two courses in a survey of astrophysics. In the first course, the instructor focuses on orbital dynamics for the solar system and binary stars. In the second course, the instructor assigns a semester project that introduces students to time-series analysis through public data from the ASAS-SN project (All Sky Automated Survey for SuperNovae; Shappee *et al*., 2014: 3; Kochanek *et al*., 2017: 7). This project focuses on eclipsing binaries, which are double stars that pass in front of each other in our line of sight, allowing for a geometric determination of the orbital size. As a result, these binaries are the best way to measure stellar masses and radii.

The biggest challenge in this course is to ensure that every student is prepared adequately for the Python scripting aspects. While they have theoretically had two semesters of Python-based courses, many students still arrive in class with some amount of programming inexperience that we must help them to overcome. To ensure that students can overcome this, the instructor has had many class sessions with Python-based demonstrations and portions of classes dedicated to ensuring that the students have seen what they need to succeed on several small projects throughout the course. It is extremely helpful for the students to have access to recorded lectures from these days, as they tend to refer to them several times for each project and Python Day.

One of the biggest challenges for physics and astronomy majors is to prepare them for a future career that involves communication through writing. Writing is becoming an integral part of the astronomical CURE, and the students finish the semester having written three sections of a paper that could eventually be submitted to a peer-reviewed journal. The writing portion of the project begins with discussions on how to write using the book, *Writing Science in Plain English,* by Anne Greene (Greene 2013). The class works through many of the exercises in the book as a class and applies them as they work through various parts of the semester-long project. The sections are assigned one at a time, beginning with an introduction to the system they have been observing, but also including a description of the observations, measurement techniques, and the model produced at the end of the semester.

Courses such as the one described are an excellent opportunity for faculty to engage students in meaningful research. Astronomers have a large toolbox of techniques to analyse light. It is a field that is wide open for discovery as new large-scale surveys come online. With a few changes in introductory material coverage, combined with instructor interest, astronomy could be a leading field for CURE implementation in the undergraduate curriculum.

Conclusion

Undergraduate research is essential for student success in graduate school and their future careers. There are many barriers preventing students from pursuing undergraduate research, as well as barriers for faculties to provide research experiences. CUREs can circumvent social, cultural, and economic barriers by providing authentic research experiences to all students. Offering CURE experiences early in the curriculum has many benefits for both students and faculty. Implementation of CUREs can be difficult, but there are various pathways for application. The trace evidence CURE for undergraduate forensic biology students has been introduced as an inquiry-based laboratory experiment that aligns with faculty research interests. Using existing equipment and supplies has saved time and resources. Forensic biology students are trained in instrumentation and laboratory techniques they will use in their upper-level courses, graduate school, and future careers as forensic scientists. In the Eclipsing Binaries CURE, students collect and analyse spectroscopic and photometric data. This project is a semester-long research project that trains students to code using Python and to write academic manuscripts. After performing this CURE, astronomy students are trained to continue this work with faculty. The benefits of adding CUREs to introductory courses outweigh any barriers to implementation. It is worth it to the students, faculty, institution, and the scientific community to make use of CUREs to educate future scientists.

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