Bridging the gap in oceanographic data science curriculum:

prototyping experiential learning materials in Python

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Abstract

The data-oriented field of oceanography asks professionals within it to be confident and capable in working with various types of oceanographic data. To develop such a skillset, individuals must have sufficient self-efficacy to continue to challenge themselves while learning (Bandura, 1977). In an effort to help aspiring oceanography professionals develop self-efficacy in data science skills, two new classes were created at the University of Washington, School of Oceanography that focused on using experiential learning to teach oceanographic data science through computer programming. These courses aimed to help students understand the importance of this skillset and encouraged the use of collaboration with peers, instructors, and outside resources to solve course problems. Student self-efficacy was assessed through surveys created by the author (who also acted as the instructor of both courses), and end of course evaluations helped examine student experience in each course. Survey results indicate that all students increased their self-efficacy in course content and had generally positive experiences learning course material through experiential learning in a small classroom setting.

Introduction

Oceanography has evolved as a data-oriented field in the past 30 years, with a major shift from small, personalized data collection via ship based measurements to mass data collection through projects like the Ocean Observatories Initiative (2018), World Ocean Atlas (NOAA, 2018), CMIP5 (Coupled Model Intercomparison Project, 2019), and many more. To analyze and utilize such vast amounts of data, computer programming techniques have been adopted by oceanographers. The increasing importance of computer programming in the field has led to an apparent disconnect between oceanography education at the undergraduate level and the direction in which oceanographic research has and continues to progress. An investigation into a few undergraduate oceanography programs illustrates that a lack of data science curriculum is common, and if it does exist, is not a requirement of the degree program (Humboldt State University, n.d.; Hawai'i Pacific University, n.d.; The University of Rhode Island, n.d.). Excluded from this list is Scripps Institution of Oceanography, which offers undergraduates numerous computational courses in the geosciences, some of which are required (University of California San Diego, 2019). The University of Washington, where this study took place, requires one course in data analysis using computer programming.

Partially relevant coursework for oceanographers is commonly offered in computer science departments. This coursework is often labeled as introductory data programming or data science. In these courses, students learn to work with simple data files (.txt, .csv) to make basic plots, learn the basics of creating scalable scripts, and write code with good style. More advanced curriculum in these departments consists of coursework like data structures and algorithms, or courses on machine learning. While insufficient due to their lack of geospatial or otherwise oceanographic content, these courses would still be beneficial to students by later expediting their ability to learn computer programming concepts relevant to the field of oceanography. However, the intimidating and competitive environment presented in computer science courses (Long, 2017) that is accompanied by student surprise and dismay when learning that computer programming is important in the geosciences (Jacobs, Gorman, Rees, & Craig, 2016) often leads to students straying as far away from computer programming as possible. These courses focus on material that go beyond the basic needs of oceanographic data scientists, who as practitioners need only act as end-users of computer programming, and therefore do not need to understand many of these concepts to begin analyzing datasets of interest.

Oceanographers need coursework explaining basic computer programming concepts and techniques, how to write scalable scripts with good style, how to work with unique data files they commonly utilize (netCDF, CNV), how to work with geospatial data, and how to create sophisticated graphics such as maps and cross sections. With the exception of the first two, which are important for writing any programming scripts, these concepts are not commonly covered in computer science courses. Oceanographers need this coursework in an environment that is separated from the aforementioned intense environment presented in computer science departments; one that allows self-efficacy in computer programming to develop and that allows them to be end-users of computer programming with oceanographic, not computer programming, goals in sight.

Two new courses were created at the University of Washington, School of Oceanography. The goals for each course focused on the development of student self-efficacy in data science using computer programming and were taught in small, experiential learning environments. Self-efficacy is a key factor in determining the activities people choose to participate in, and affects the length of time individuals choose to keep working on difficult tasks (Bandura, 1977). Because of this, its development is key for individuals to begin and continue challenging themselves while they develop skills such as those needed in oceanographic data science. Furthermore, the small learning environment is similar to those found in coding bootcamps, which are often highly praised for their ability to work closely with students who act as end users of computer programming (Harvard, 2018; UC Berkeley, 2019; Eggleston, 2019), and experiential learning is known as a proven educational technique (Winn et al., 2006; Freeman et al., 2014). In today’s data-oriented world, experiential learning in oceanography does not just mean being in the ocean; it means working with data from the ocean.

The course assessments, student surveys, and course projects are used to evaluate the success of this teaching approach. The implementation of pedagogical tools and the structure of the courses are described along with descriptions of key instructional benefits and challenges realized in this type of learning environment. The key objective is to evaluate the student’s outcome for self-efficacy for using computer programing in oceanographic data analysis.

Methods

A data science curriculum needs analysis was performed via interviews conducted with two faculty members at the University of Washington, School of Oceanography; Dr. Mikelle Nuwer and Dr. Susan Hautala. Dr. Nuwer is a lecturer in the school who frequently works with students and instructs introductory undergraduate coursework. Dr. Hautala is an associate professor and past associate director for undergraduate education in the school. From these interviews, relevant course material in accomplishing the goals of each class was determined. These two faculty members significantly impacted the design of course materials for both OCEAN 240 and OCEAN 340.

OCEAN 240 course environment

OCEAN 240 was taught in the winter quarter of academic year 2018-19 as an elective course available to all majors. The course enrollment included seven undergraduates, all from majors within the College of the Environment, including a few that had declared oceanography as their major. The computer programming backgrounds varied as did the stated goals of the students with only one student having any previous programming coursework, though two were concurrently enrolled in programming courses.

This one credit, pass-fail course was designed for students who had never written code before. The goal of the course was for students to understand the importance of computer programming in the field of oceanography and build confidence in their ability to write code. It was not to teach students how to write stylistic, efficient code. Instead, it was to help students experience what writing code is like and understand why it is important in the field of oceanography, aimed at providing a “soft” introduction to this type of material to students. The class met once per week for a period of one hour and twenty minutes to work together and complete an assignment.

OCEAN 340 course environment

OCEAN 340 was taught in a small class, with an enrollment of 10 students. All students had taken the one computer programming course offered in the University of Washington, School of Oceanography; OCEAN 215. Coming into OCEAN 340, students were expected to understand and have experience with basic computer science concepts (variables, loops, one dimensional arrays), read in data from text files to then analyze data using these concepts, and make basic plots of this data. Students in OCEAN 340 ranged from second year to fourth year students, and many goals of using computer programming in a professional setting in the future.

This three-credit graded course was designed to teach students how computer programming is used in a professional setting and begin performing complex tasks relevant to oceanographic data analysis (specifically those mentioned in the above assignments). Class met twice per week for an hour and fifty minutes.

Self-efficacy in oceanographic data analysis assessment

Surveys were created for each course to determine (1) perceived current self-efficacy at a current point in time, and (2) perceived self-efficacy at the beginning of the course, which was evaluated at the end of the quarter. Survey formatting and presentation was designed based off of work by Bandura (2006) and questions were aimed at determining self-efficacy in course concepts. Each survey contained a practice item to help familiarize participants with the survey. Surveys were pre-tested to ensure that the material was presented clearly.

Survey A was given to OCEAN 340 during week seven. This was the final week of regular class instruction, as weeks eight to ten consisted of special topics lessons and lessons surrounding the final project for the course. For this reason, the question on of the course environment (figure 7) was presented at this time rather than week ten to be most representative of the majority of the experience in the course. Survey B was given to OCEAN 340 during week ten. This survey was very similar to the survey distributed during week seven, but additionally asked about perceived self-efficacy in course content at the start of the quarter in an effort to track change. Survey C was given to OCEAN 240 during week ten, and similar to Survey B, targeted understanding current self-efficacy in course content and perceived change in this self-efficacy throughout the course.

Course evaluations

A custom course evaluation was created for both OCEAN 240 and OCEAN 340, borrowing questions from standard course evaluations created by the University of Washington, Office of Educational Assessment. This custom evaluation was used to obtain specific information that the teaching team felt was most relevant to both of these courses, which varied from other types of courses offered at the University of Washington, and therefore no standard survey was ideal. Survey D, found in the appendix, was given to both OCEAN 240 and OCEAN 340 during the final meeting of each course in week 10.

Results

OCEAN 240 and OCEAN 340 material generally focused on physical oceanography. The basics of web development were also included in each course for two reasons. First, it is common for practitioners to obtain a skillset and settle with it. Understanding that there is a significant amount to learn in the technology field outside of one form of data science is important for encouraging evolution and growth of skillsets in an ever-changing field. Second, students used web development to display their final projects online.

OCEAN 240

Course material

Course material included understanding and using basic computer science concepts including variables, for loops, lists, and reading files in an effort to create figures or statistics that could be analyzed. Assignments included sediment particle classification based on random data values (Appendix A1), reading in data from CNV files to create plots and maps of the profiles (Appendix A2), creating a time series plot of a variable of the student's choice from a text file accompanied by some basic web development (HTML, CSS) to display this time series plot on a webpage (Appendix A3), and more. Python packages used include *matplotlib, seawater, numpy, cnv*, and more.

The course material was created with the objective of helping students develop confidence in their programming ability, prepare them for future coursework using computer programming in the field of oceanography, and give insight as to why oceanographic data scientists use computer programming. This was done in an effort to first understand the importance of gaining a skill (computer programming), before learning the skill itself. The task of learning oceanographic data science would be given to students in later introductory coursework, while they take this understanding of application with them. Giving students a reason for learning the skill, which this class aimed to do, was intended to help them when they begin learning and applying computer programming in a less supportive setting.

Course environment

The assignments in the course consisted of multiple parts, and the instructor and students worked together to tackle each part of the assignment, often broken up into small increments that were due each week. Material was presented to the class in a manner that first addressed a situation and its context, and then together (through a combination of the instructor asking relevant questions and students answering), the class addressed each situation through programming. Students were encouraged to ask questions, work together and/or use outside resources when they encountered problems. Essentially all work was completed together in class (with the exception of work being done by students via following two video tutorials that were released online when class was cancelled due to inclement weather). Assignments were graded based upon completion.

OCEAN 340

Course material

Course material included reading and writing data from various file formats relevant to oceanography (netCDF, CNV, CSV), working with multi-dimensional data, creating complex plots (maps, cross sections, vertical profiles), and writing scalable, functional scripts with good code style. Assignments consisted of writing to various file types (Appendix A1), reading and analyzing World Ocean Atlas data (NOAA, 2018) to create maps (Appendix A2), creating cross sections from CNV profiles (Appendix A3), and more. At the end of the course, students were asked to complete a three-week final project on a topic of their choice, using skills that were developed in class. This was meant to demonstrate learning, as students tackled a complex, real-world dataset of interest and were asked to complete their analysis by writing code that was functional, scalable, and had good style. Example final projects can be found in the appendix (FP1, FP2).

Course environment

Similar to OCEAN 240, the assignments consisted of multiple parts, and the class would work together to first understand the scope and context of a problem, then diagnose how to solve it through code. Students were encouraged to work together in groups, with the teaching team, and use outside resources to solve problems they encountered. The instructor led students during the first hour of class via prompting them with questions related to solving homework problems. At times, students would be given five to ten-minute periods to use outside resources and work together in groups on a question given by the instructor and then reconvene to discuss their findings. During the second hour, assignments were worked on either in groups or individually by students at their discretion, and the instructor attended to questions. Students were expected to spend approximately five hours per week outside of class to complete homework assignments.

Additionally, as students were able to work together and use outside resources, this presented students with an atmosphere that was less intimidating than many technical courses, which contain a rigid structure and harsh penalties for group work. Students frequented office hours throughout the course; it was common to find five or six students attending an office hour session. Students rarely appeared stressed during office hours, and the author believes they generally attended due to understanding they could work collaboratively with other students and the instructor at that time. Students were asked to collaborate by only discussing ideas, not specific lines of code, which was clearly stated in class and on the syllabus to be against course policy.

Results of self-efficacy assessment

The teaching team and a Ph.D candidate in his final year of physical oceanography were consulted to determine 1) what is course material that is relevant for oceanographic data scientists to learn, and 2) of this course material, what was taught in OCEAN 240 and OCEAN 340. The results of these discussions were the topics assessed in the self-efficacy survey of the courses. Survey results indicated a high level of self-efficacy in course content by students at the end of the quarter, and a perceived increase in self-efficacy over the course of the quarter. Please see each survey (A, B, C) in the appendix.

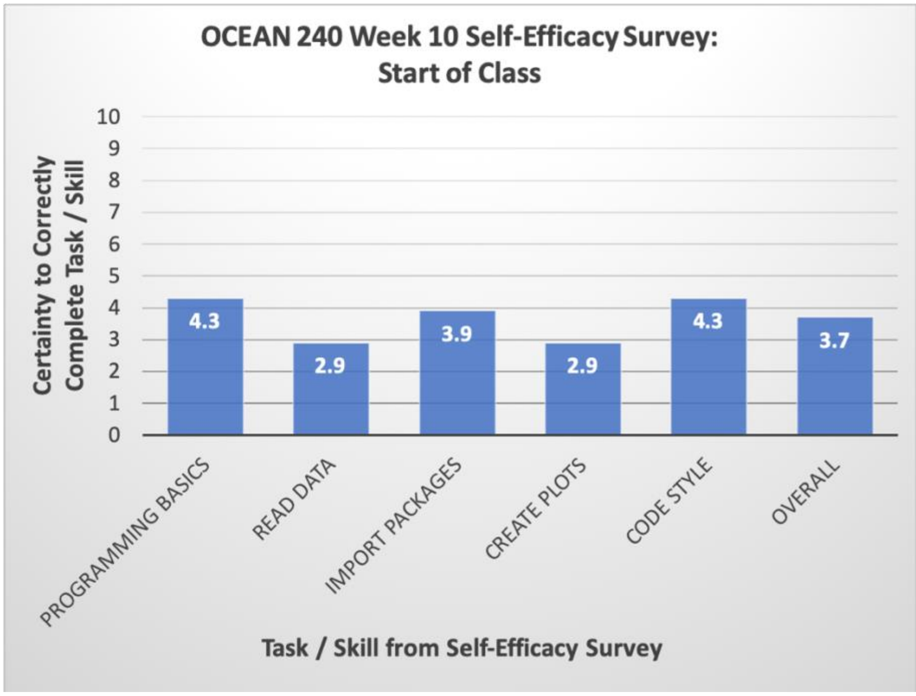

Figure 1. A comparison of the average view of students in OCEAN 240 to different questions designed to assess their perception of confidence about the course content at the beginning of class. See Survey C in the appendix for details.

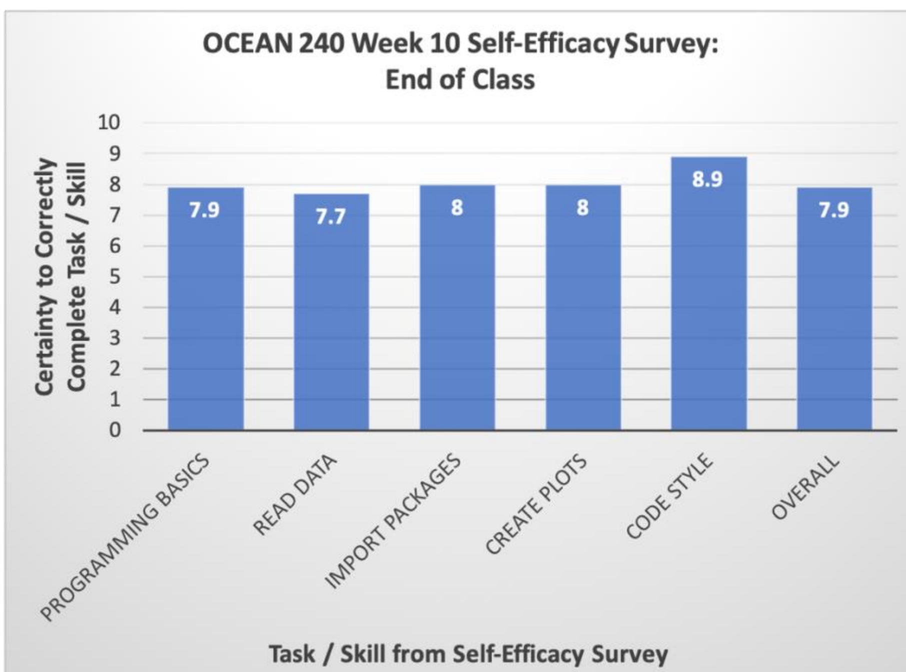

Figure 2. A comparison of the average view of students in OCEAN 240 to different questions designed to assess their perception of confidence about the course content at the end of class. See Survey C in the appendix for details.

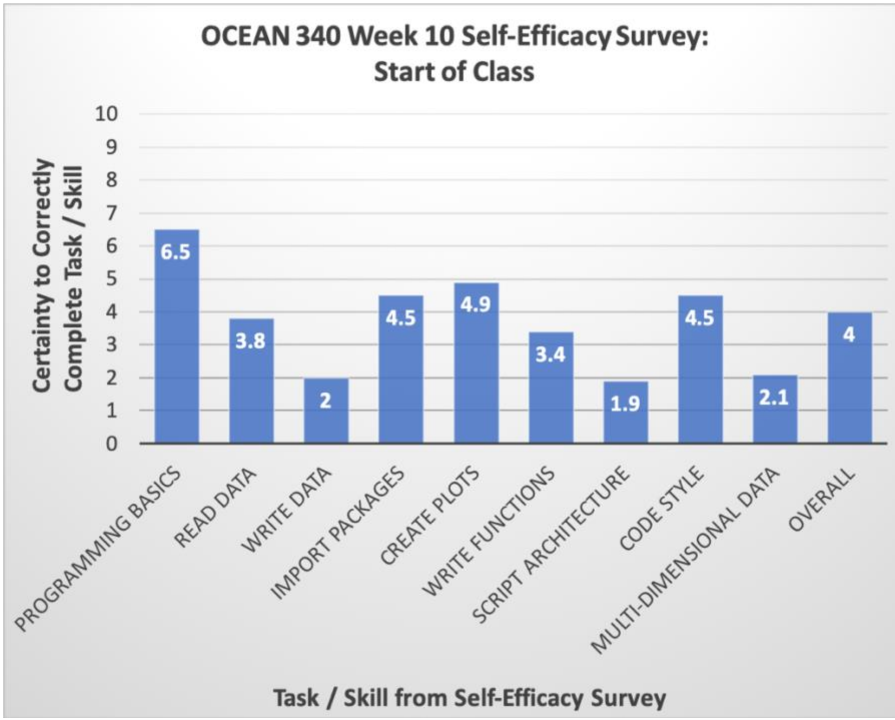

Figure 3. A comparison of the average view of students in OCEAN 340 to different questions designed to assess their perception of confidence about the course content at the beginning of class. See Survey B in the appendix for details.

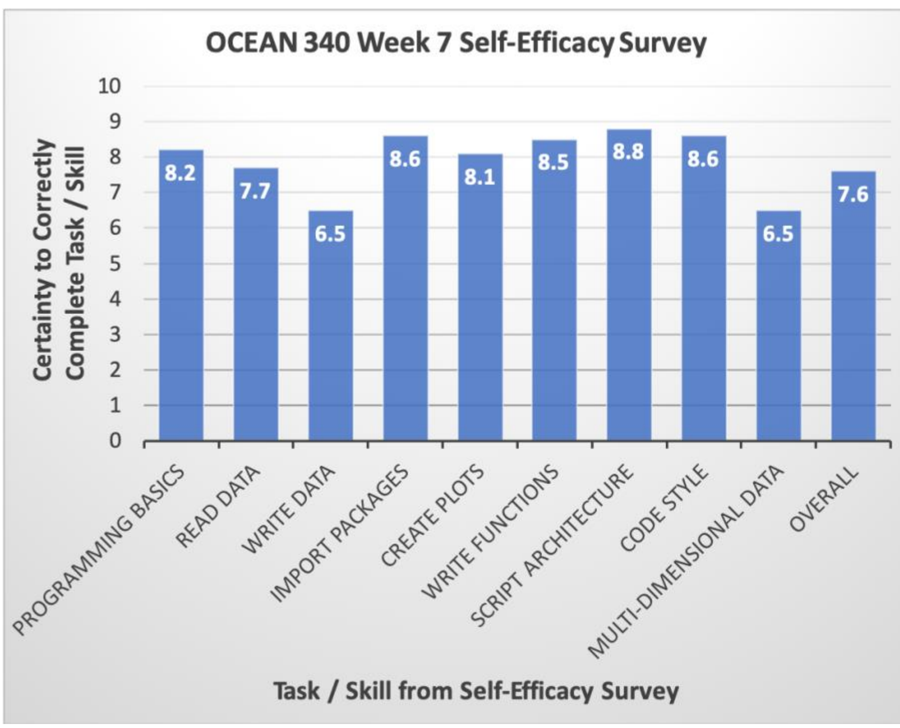

Figure 4. A comparison of the average view of students in OCEAN 340 to different questions designed to assess their perception of confidence about the course content during week seven of class, the point at which normal course instruction ended and students began work on final projects. See Survey A in the appendix for details.

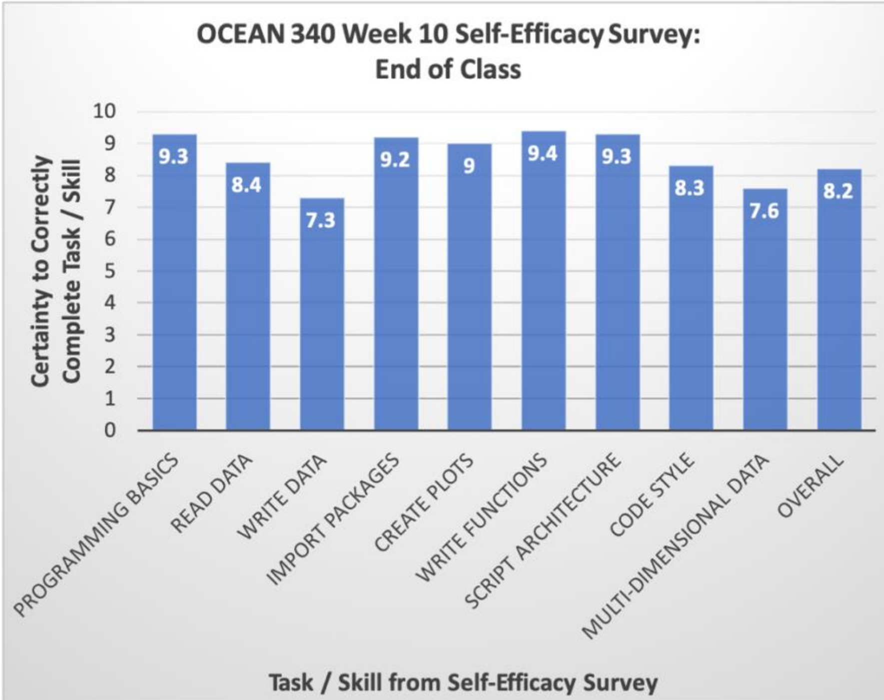

Figure 5. A comparison of the average view of students in OCEAN 340 to different questions designed to assess their perception of confidence about the course content at the end of class. See Survey B in the appendix for details.

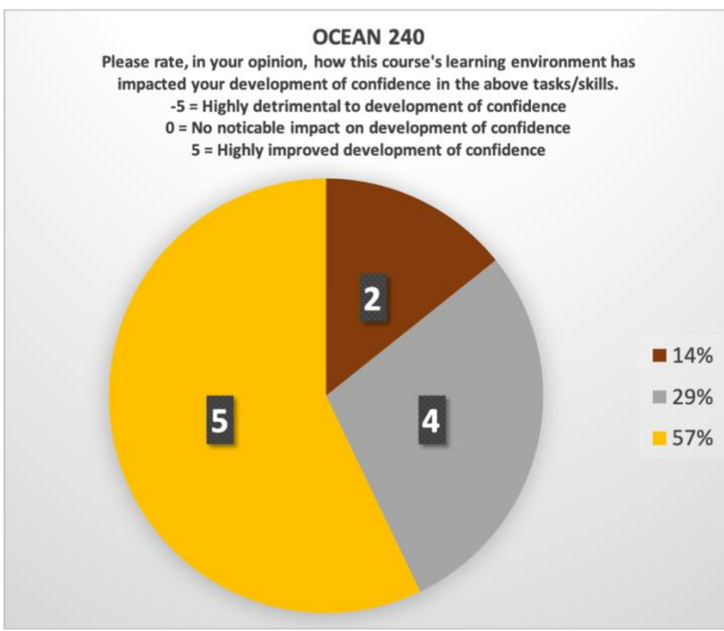

Figure 6. A comparison of student responses to a question addressing student experience in the course environment presented in OCEAN 240. Note the scale being different than that of other questions: negative five to positive five.
See Survey C in the appendix for details.

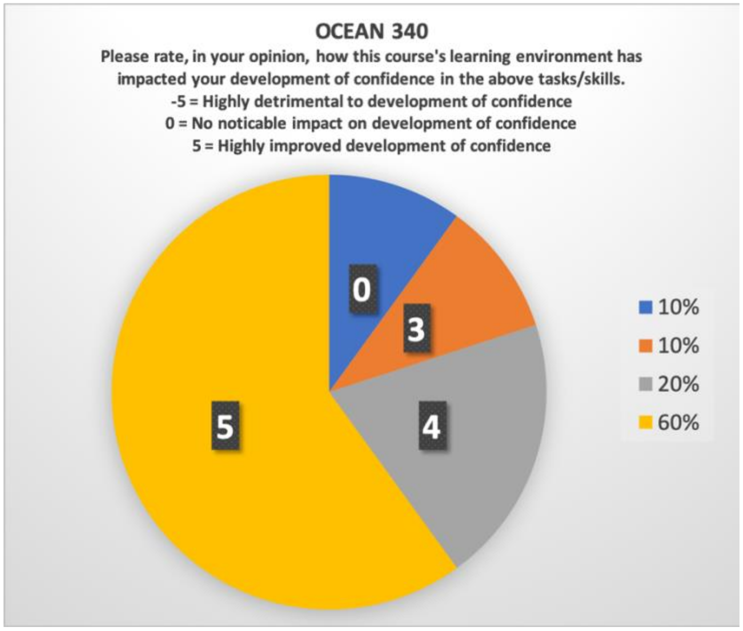

Figure 7. A comparison of student responses to a question addressing student experience in the course environment presented in OCEAN 340. Note the scale being different than that of other questions: negative five to positive five. See Survey A in the appendix for details.

Results of course evaluation

The course evaluation completed by students consisted of a variety of questions created by the University of Washington, Office of Educational Assessment. Questions with the most relevant material, and their accompanying answers by students, are described below.

When OCEAN 240 and OCEAN 340 students were asked the question:

Q1: "What aspects of this class contributed most to your learning?"

OCEAN 240 students stated the following:

A1a: "The way the in-class assignments were follow along examples instead of just watching and trying to remember."

A1b: "Being able to walk through the code and understand every part of what we were writing. As someone who has never written code before, it was helpful to be able to ask questions about the things I didn't know about with the small group."

And OCEAN 340 students responded with:

A1c: "I really loved doing the homework as an in-class activity and I strongly enjoyed the focus on the application of coding on oceanographic studies."

A1d: "When we followed along in class to what you were doing, it made it easier to learn when we were actually coding ourselves."

When OCEAN 240 and OCEAN 340 students were asked the following question:

Q2: Overall, was this course valuable to your education? Since this is the first time this course has been taught, please let us know whether you believe it would be a good addition as an elective to the UW School of Oceanography's undergraduate curriculum, and why or why not. Any other feedback you have for us is also welcome.

All responses from both classes were positive, indicating that the students found the course they took valuable to their education. Below are quotes from OCEAN 240 students:

A2a: "This course was definitely a valuable introduction to programming. Even not being an ocean major I felt like the skills learned were widely applicable and it was cool to learn a little bit about oceanography along the way. It seems like a very useful course to offer. It was particularly beneficial in with such a small class size because it was so easy to ask questions."

A2b: "I think it was very useful. I have done barely any coding before so it was a very approachable, low-stakes introduction to coding that helped get me started in coding."

And from OCEAN 340:

A2c: "This course was incredibly valuable to my education. It picks up from where [OCEAN] *215 leaves off very well and brings serious and relevant data analysis skills to the table. This course gave a huge boost to my understanding of coding and gave me a lot of confidence in my ability to use python as an aid in manipulating and visualizing data. I think that* [OCEAN] *340 should absolutely be added to the oceanographic curriculum as an elective and I would strongly recommend this course to any of my peers. If there were a third quarter of oceanographic data analysis, I'd take it in a heartbeat!"*

A2d: "I do think this course was a good addition to my education. Taking [OCEAN] *215 was definitely helpful to lay some of the basic groundwork behind coding. However, I think this course taught me how to apply those skills to actual research and taught me how to figure more things out for myself."*

Students were also questioned to determine any factors that were detrimental to their learning:

Q3: "What aspects of this class detracted from your learning?"

Two of seven OCEAN 240 students responded by saying that nothing was detrimental, and another two stated that the two cancelled classes due to inclement weather were detrimental. The following are two quotes from students who did find some course content detrimental:

A3a: "Sometimes the discussion went on a little longer than needed."

A3b: "I feel like parts of what we learned did not have very high retention. I don't know if I remember everything that we have learned…"

Three respondents to the OCEAN 340 survey stated that there was nothing detrimental. Other responses included the following:

A3c: "The problem sets were great because they walked through the overview of what was expected, however sometimes the expectations were a little difficult to decipher at home when we couldn't ask questions."

A3d: "Lack of class notes."

Last, it should be noted that students were asked a variety of general questions about their experience in the course, including instructor interactions / contribution, and comparisons of experience to other college courses they had taken. Notably, students were asked the following question:

Q4: "Relative to other college courses you have taken, the amount of effort required to succeed in this course was:

Much higher, Somewhat higher, Average, Somewhat lower, Much lower"

In OCEAN 240, student responses varied from "Average" to "Much lower" with a median response of "Somewhat lower". In OCEAN 340, student responses varied from "Average" to "Much higher" with a median response of "Somewhat higher".

Analysis of self-efficacy survey and course evaluation

Assessments showed perceived increases in self-efficacy by all students on course material. The methodology used was not ideal, as students should be surveyed at the beginning of the course on their self-efficacy of course content and then again at the end of the course. However, due to the instructors only broadly knowing the goals of the course, and specific content not being planned until days before each class, it was not possible to survey well at the beginning of class.

Qualitative data from additional surveys aligns with the findings of the self-efficacy surveys, as they identify that students found great value in both the instruction (ex. *response A1a)* and course material (ex. *response A2c)*. Students did find some material detrimental. Responses to this prompt varied significantly between OCEAN 240 and OCEAN 340. For OCEAN 240, it appears that students had a range of experiences in class, from material going on too long, to material not being explained well enough for high retention. In OCEAN 340, student responses to this question indicate that experiential learning becomes challenging when (1), students were no longer able to ask questions in the comfortable and collaborative class environment, and were forced to work on their own at home, and (2), a lack of class notes being distributed led to a detrimental learning experience at times. Students also rated this class as generally requiring a greater than average effort to succeed. In general, feedback by students from both courses is interpreted by the author as positive.

Discussion and Conclusion

The course material and classroom environment of both courses varied in intent and focus of the content and presented students with different challenges for developing their skills. The experience of the instructor, as well as the result of the self-efficacy assessments, provided insights into future teaching approaches for experiential learning in data science, and suggests unique opportunities exist for advancing undergraduate ocean science education.

OCEAN 240: Course material and environment

The instructor aimed to avoid the isolating feeling that is too often presented in programming by prompting students in a group setting, rather than an individual setting. He explained to students that oceanographers are end-users of computer programming and use it to accomplish oceanographic goals, and constantly kept close to the context of the problem while programming with students in class. This appeared to help students shift from being intimidated by programming to understanding that oceanographic problems can be addressed well through programming. Creating this shift was of great importance to the instructor, and he was pleased to find his expectations of how to accomplish this were met.

The environment created in the class, one that contained experiential learning and group work, brought students together both academically and socially. By the third meeting of class students appeared comfortable around one another. This quick shift came as a pleasant surprise to the instructor due to the diverse backgrounds of students. Students reported in the final course assessment that they appreciated the small nature of the course, and it made them feel free to ask questions. The median response of "somewhat lower" effort needed to succeed in the course met the expectation and desire of the author. These responses in the course evaluation were important factors in the course environment, which the author credits as the foundation upon which student self-efficacy grew.

The author was pleasantly surprised by the enjoyment students had in learning course material. It was clear that the students wanted to be in class, and no student ever missed class. While participation was 50% of the grade for students, this meant that students could have missed two classes and still received credit for the course. Students were constantly engaged, asking questions that generally were spoken in pseudo-code, aimed at accomplishing a task relevant to the context of the assignment in oceanography. This met the intention of the instructor and persisted throughout the course.

If a student were to miss class, making up an assignment would have been difficult for them. For this reason, recording lectures may be helpful in future iterations. Additionally, assignments consisted of following along with the instructor. Appending a series of relevant questions to the end of the assignment may be beneficial to further understand what students take away from each assignment and what should be changed in the future.

OCEAN 340: Course material and environment

The goal of increasing student self-efficacy in course content was met, and students appeared to have an enjoyable yet challenging experience in the course. Students who were originally doubtful of their ability to program well were able to counter these fears by writing code in class, which provided students with a more mellow introduction to material than expecting students to work on everything by themselves outside of class. This type of introduction to complex ideas and skills was necessary due to the intimidating nature of programming mentioned earlier in this paper. Students appeared to develop a sense of freedom by working together and using outside resources. While much introductory coursework constrains students in their ability to solve problems, the opposite approach was granted to students in this course, with the goal of being able to solve a problem presented to them by any means necessary besides copying code from others in the course. This approach, one much more commonly found to be relevant to oceanographic data science practitioners from the needs analysis that was conducted and the author’s experience as a practitioner, created less frustration for students and a greater sense of understanding of what this type of work is like for practitioners in this field. The author believes that this freedom students found in their work, and the action of writing code collaboratively in class, greatly impacted the self-efficacy increase reported by every student and created positive yet challenging experiences in the course.

Students frequently attended office hours. This was unexpected, but the positive atmosphere that occurred during office hours was reassuring to the instructor that students were arriving for reasons not promoted solely by stress, but at least somewhat by an understanding that they could receive help in that environment, whether it be from the instructor or peers. Students did note in the course evaluation that the parts of the course detrimental to learning surrounded working in isolation, which office hours did help address.

Students created final projects that were very broad in scope. Projects included everything from a sediment distribution model, to a video tracking an Argo Float on a map and the data being collected (appendix FP1), to high definition maps of seafloor bathymetry (appendix FP2). This scope, some of which was outside of what was covered in the course, created very impressive projects. The variety of projects is likely a result of encouraging students to pursue projects of interest, not bounding students to specific resources / ways of solving their problems in the class.

In future iterations of the course, the author recommends a heavier emphasis on newer, common modules like *xarray* and *pandas* to conduct analysis. These modules, which are built on top of modules focused heavily upon in the courses such as *netcdf4* and *numpy*, allow for easier analysis of oceanographic data. Both *xarray* and *pandas* are used by practitioners in their work and are considered by the author to be superior in accomplishing common tasks in oceanographic data analysis compared to the modules they are built upon.

Conclusion

Undergraduate oceanography data science curriculum needs were assessed in the University of Washington, School of Oceanography. This assessment created the basis for two new courses, OCEAN 240 and OCEAN 340, and these courses were tested for their use of experiential learning to develop student self-efficacy in oceanographic data science. Results from course assessments and self-efficacy surveys indicate that all students developed self-efficacy in course content through the course material and environment. Most notably, this was done in OCEAN 340 through demanding coursework, indicating that undergraduate oceanographers can be challenged to learn this material, enjoy the experience, and learn a valuable skill set that may empower them in their careers.

Future

Since each course ended, multiple students have personally reported to the author the benefits of taking each course and that they have used what they learned in both research and educational settings. Teaching this type of coursework using experiential learning offers students the opportunity to overcome initial dismay and intimidation of computer programming and allows them to see the benefits in using it to analyze oceanographic data.

This study should be viewed as a way to adequately develop student self-efficacy in aforementioned course material, which has been stated by multiple members of the University of Washington, School of Oceanography to be valuable content for oceanographers. This course material is encouraged to be developed and implemented in undergraduate oceanography curriculum at other universities in a much-needed effort to educate and train the future leaders of the field. It is unnecessary for students to postpone learning this material until a time when it is needed to conduct analysis of interest. Equipping students with this skill set as undergraduates empowers student understanding of oceanographic data science and increased self-efficacy in this matter empowers students to take on daunting tasks before being required to, in turn promoting student drive, confidence, and capability.

References

Bandura, A. (2006). Self-efficacy beliefs of adolescents. Guide for constructing self-efficacy scales, 5, 307-37.

Bandura, A. (1977). Self-Efficacy: Toward a Unifying Theory of Behavioral Change. *Psychological Review*, 191-215.

Coupled Model Intercomparison Project. (2019). *Overview*. Retrieved from Lawrence Livermore National Laboratory: https://cmip.llnl.gov/cmip5/index.html

Eggleston, L. (2019, April 8). *Learning Data Analytics via Experiential Learning at Level*. Retrieved from Course Report: https://www.coursereport.com/blog/learning-data-analytics-via-experiential-learning-at-level

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wendorth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 8410-8415.

Harvard. (2018, December 4). *Harvard Extension School and Trilogy Education Launch Coding Boot Camp in Cambridge*. Retrieved from Harvard: https://www.extension.harvard.edu/harvard-extension-school-trilogy-education-launch-coding-boot-camp-cambridge

Hawai'i Pacific University. (n.d.). *Undergraduate Program*. Retrieved from Hawaii Pacific University: https://www.hpu.edu/registrar/academic-catalog/view-undergrad.html#?p=BSOCN

Humboldt State University. (n.d.). *Oceanography*. Retrieved from humboldt.edu: https://www.humboldt.edu/programs/oceanography

Jacobs, C. T., Gorman, G. J., Rees, H. E., & Craig, L. E. (2016). Experiences With Efficient Methodologies for Teaching Computer Programming to Geoscientists. *Journal of Geoscience Education*, 183-198.

Long, K. (2017, February 24). *Students frustrated trying to get into UW's competitive engineering program*. Retrieved from The Olympian: https://www.theolympian.com/news/local/article134866984.html

NOAA. (2018). *Access to WOA 2018 data*. Retrieved from NOAA: https://www.nodc.noaa.gov/OC5/woa18/woa18data.html

Ocean Observatories Initiative. (2018). *Data Portal*. Retrieved from Ocean Observatories Initiative: https://oceanobservatories.org/data-portal/

The University of Rhode Island. (n.d.). *Degrees, Majors, and Fields of Study*. Retrieved from The University of Rhode Island: https://web.uri.edu/catalog/degrees-majors-and-fields-of-study/

UC Berkeley. (2019, April 15). *Berkeley Coding Boot Camp*. Retrieved from UC Berkeley: https://bootcamp.berkeley.edu/coding/

University of California San Diego. (2019, February 6). *Scripps Institution of Oceanography*. Retrieved from University of California San Diego: https://www.ucsd.edu/catalog/curric/SIO-ug.html

Winn, W. , Stahr, F. , Sarason, C. , Fruland, R. , Oppenheimer, P. and Lee, Y. (2006), Learning oceanography from a computer simulation compared with direct experience at sea. J. Res. Sci. Teach., 43: 25-42. doi:10.1002/tea.20097

Appendix

Surveys

Survey A: http://bit.ly/OCEAN-340-week7-survey

Survey B: http://bit.ly/OCEAN-340-week10-survey

Survey C: http://bit.ly/OCEAN-240-week10-survey

Survey D: http://bit.ly/OCEAN-course-evals

Assignments

OCEAN 240 (Available upon request, need GitHub account):

A1: http://bit.ly/OCEAN-240-A1

A2: http://bit.ly/OCEAN-240-A2

A3: http://bit.ly/OCEAN-240-A3

All OCEAN 240 Assignments: http://bit.ly/OCEAN-240

OCEAN 340 (Publicly available):

A1: http://bit.ly/OCEAN-340-A1

A2: http://bit.ly/OCEAN-340-A2

A3: http://bit.ly/OCEAN-340-A3

All OCEAN 340 Assignments: http://bit.ly/OCEAN-340

FP1: http://bit.ly/OCEAN-340-FP1

FP2: http://bit.ly/OCEAN-340-FP2