The impact of computation in the classroom on independent research experiences

As more students are considering entering the STEM field, they are entering STEM classes with a broad range of preparation. Unfortunately, many students do not have previous computer programming experience. In addition, many students do not have their own computers and are not well versed navigating their computers, installing software, or learning new software packages. This puts these students at a disadvantage pursuing independent research opportunities.

Professors often have unrealistic expectations for college students. They expect a certain level of competence with computer hardware, navigation, and programming. This may be because the prior generation grew up with computers where the user interface wasn't nearly as well developed. Many STEM professionals tinkered with computers, hardware, and coding in their early careers. This leads to an expectation that "serious" or "legitimate" science students will have had these experiences as younger students when this is more often not the case.

Training of students needs to start at the beginning. The learning curve for college students is very steep. Instead of starting with Scratch or Logo or Alice as we do with younger students, we expect college students to jump right into text-based coding. This is often intimidating and causes students to believe they aren't good at coding. When, coding is just like playing a sport or instrument, time on task leads to success.

Without dedicated time spent learning how to code and using computational tools, students:

-Lack confidence with the skills.
-Lack of confidence causes students to question their career goals.
-They see their skills are far behind their peers with prior experience and get discouraged.

In the department of physics and astronomy at Siena College, we've made it a priority to increase access to coding and simulation tools for physics students across the curriculum. Students are strongly encouraged to pursue paid research opportunities in the summer through an endowed undergraduate research program as well as through funded faculty research programs. For the past two summers over 30 students pursued research experiences on campus and an additional 4 students participated in REU programs.

Many of our incoming freshmen have no coding experience which makes it difficult for them to participate in research right away. As a faculty, we've committed to provide opportunities throughout the curriculum to allow students to participate successfully in research. As incoming freshmen, physics majors are placed in a course called Software Tools for Physicists. This course replaces their requirement for a computer science course and is taught by a physicist and was designed with input from the physics faculty. Students learn python using jupyter ipython notebooks. At the same time, jupyter ipython notebooks are used in their general physics lab to plot and fit their data.

Their fall semester sophomore level electronics course is no longer focused on traditional homework problem sets and instead employs richer project-based assignments that includes calculations, computation, and modeling of traditional examples. In this course, they complete labs and analyze their data in Matlab as well as model electronic components in Matlab and Simulink. They also write scripts and functions to verify their calculations of traditional problem sets.

Computation continues in a spring sophomore level computational physics course where Matlab is used to model many different physical systems in Matlab. The course culminates in a final project of the students' choosing.

Computation is threaded through the junior courses as well with a mechanics course that includes a three-hour lab. Students plot and analyze their data in python. Computational tools are used in their experimental techniques course and computation is being added this spring to the electricity and magnetism course.

Finally, students are required to complete a senior independent research course. Most of these projects involve some sort of computation.

Anecdotally, students leaving our program have marketable computational skills. All of the REU student projects were computational in nature. Alumni return and let us know that their computational skills helped them to get their first or second job and that they use computational tools regularly in their careers.