Measuring the Impact of Introducing Computation in Introductory Physics Courses: The STEMcoding Project

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Abstract

Computation has become a standard tool for practicing scientists and engineers. Educators and education researchers have been working to find the best ways to integrate this into the curricula at all levels to best prepare students for careers in STEM fields. The STEMcoding project integrates programming activities in introductory physics courses at the high school and undergraduate level [1,2,3]. I analyzed pre- and post-assessment data from the Fall 2017, Spring 2018, and Fall 2018 semesters of General Physics II at the University of Mount Union and compared this data with results from the Brief Electricity and Magnetism Assessment – a nationally recognized undergraduate physics assessment [4]. I analyzed how students answered a few basic conceptual questions before and after completing the STEMcoding activities to see if the activities helped provide a better understanding of those concepts. I also compared the STEMcoding assessment results to the BEMA results to see how the context of these questions reflected students understanding of certain physical concepts. This work will contribute to the pursuit of integrating computation into classrooms to prepare students for STEM careers.

Background

The STEMcoding Project teaches students fundamental physics concepts through the use of computer programming activities ranging from velocity and acceleration to electricity and magnetism [1,2,3]. These activities were introduced to students taking an electricity and magnetism introduction physics class at the University of Mount Union during the Fall 2017, Spring 2018, and Fall 2018 semesters. Most of these students are sophomores and juniors and 82% are STEM majors, however, 73% had never written or modified a computer program before.

STEMcoding Activities

Introductory activities teach students the basics of the p5.js computer language that is used in all the activities and some useful troubleshooting tips. These coding activities start with part of the code already written and some are framed in the context of a videogame like Pong or Bonk.io [5]. Most activities also include pre- and post-quizzes to test students' knowledge about the physical concepts before and after completing an activity [3,4]. Some examples of the activities are shown below.

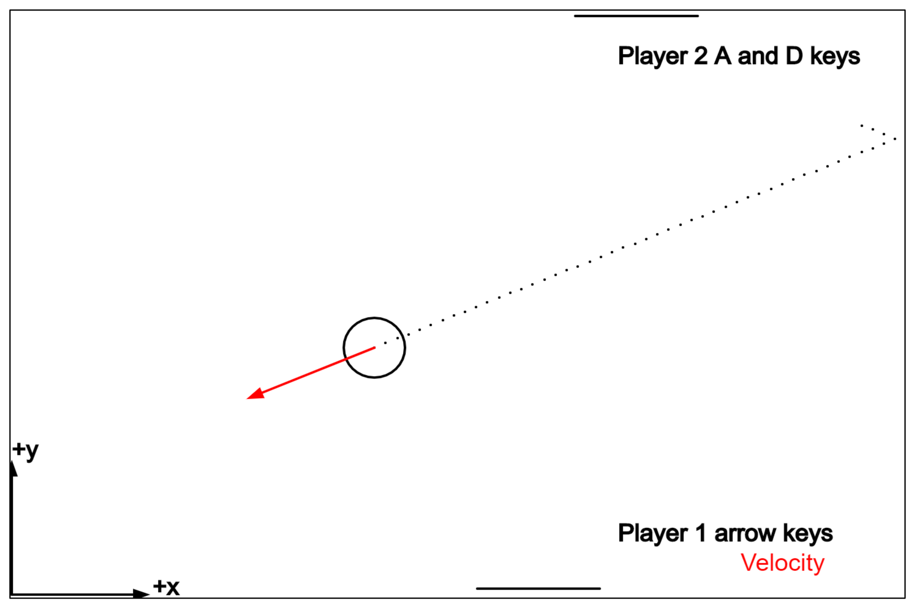

Figure 1 to the left shows the Pong Game activity where students learn about elastic collisions [5].

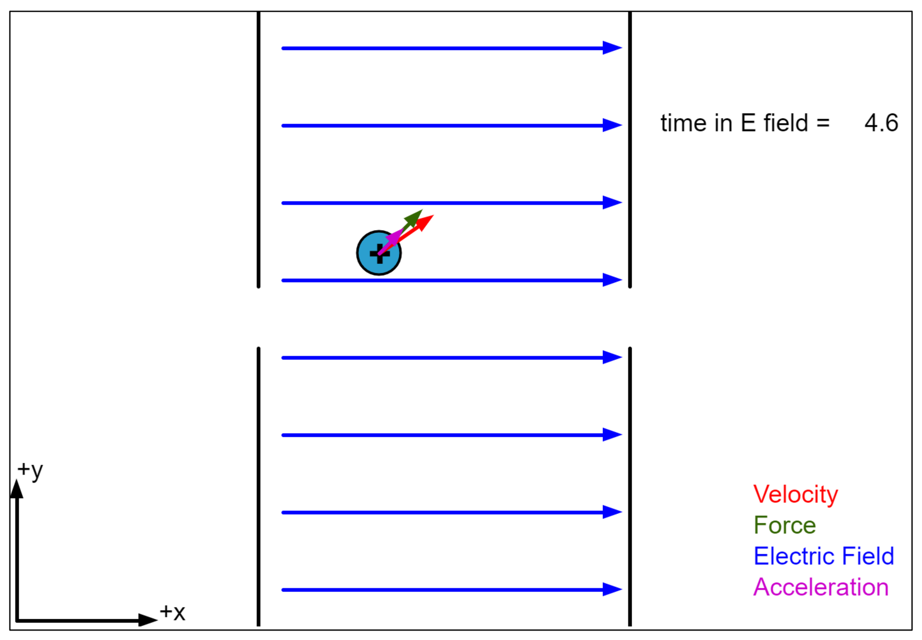

Figure 2 to the left shows the Particle Accelerator activity where students explore the behavior of a charged particle in an electric field between two plates [5].

Results

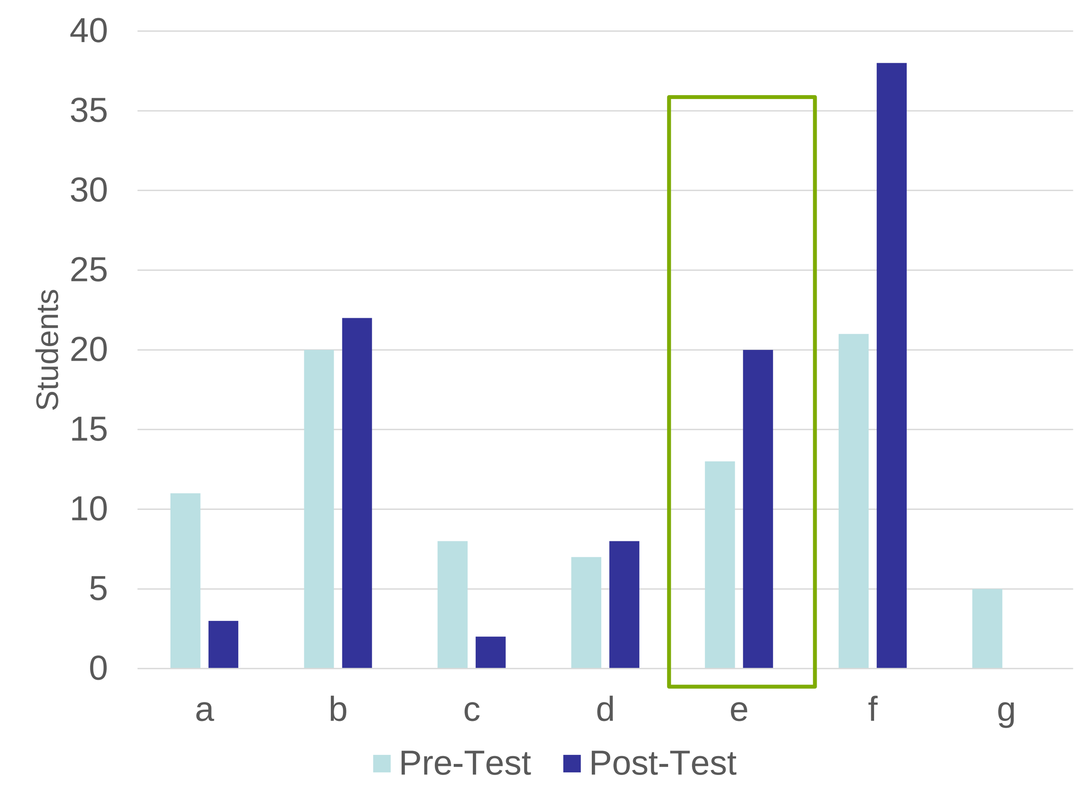

Figure 5 above shows the results from the BEMA question of what direction a magnetic field would point inside the shaded area to cause this path of travel for a negatively charged particle [4]. This produced the desired result before and after taking General Physics II.

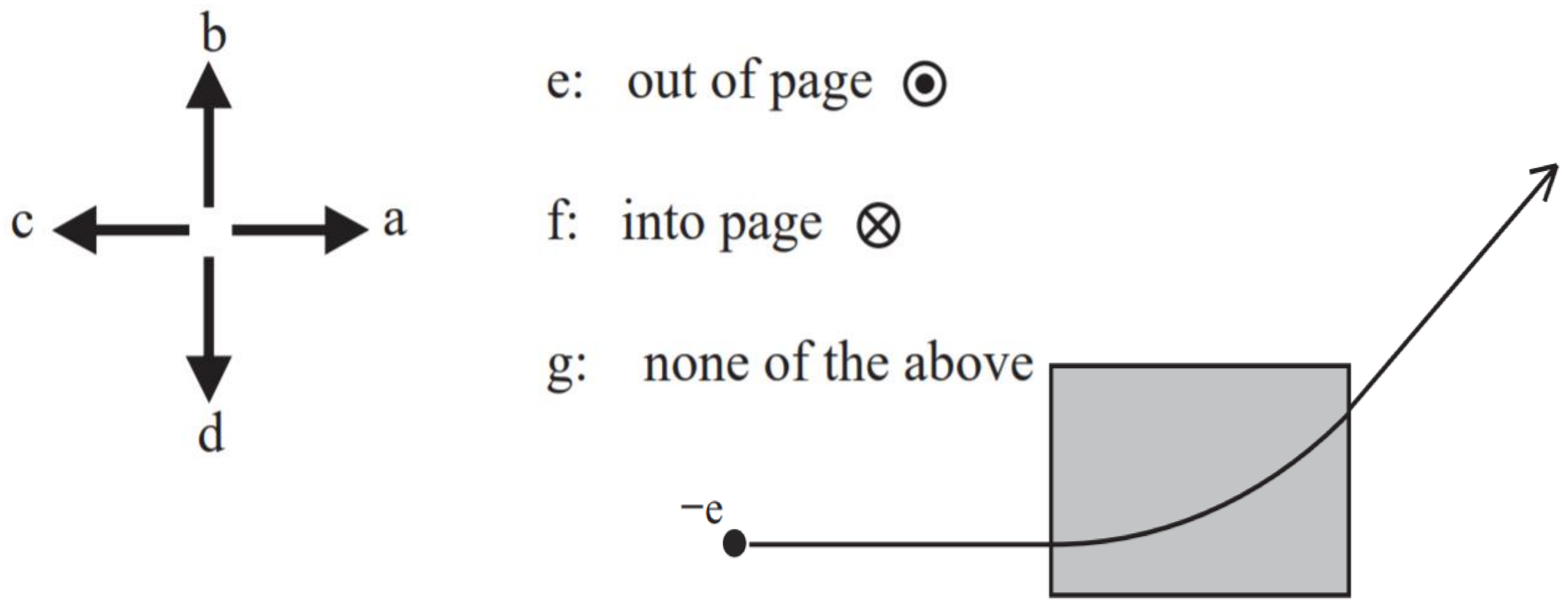

Figure 6 above shows the figure used in some of the BEMA questions that the results in Figures 4 and 5 are referencing [4].

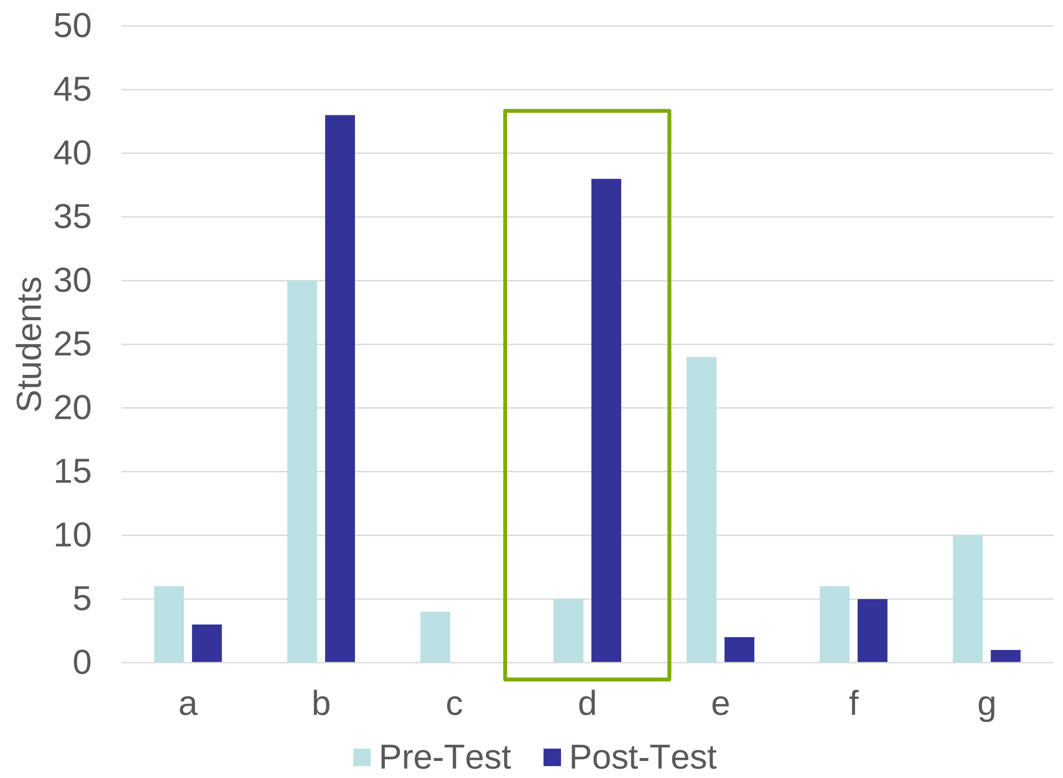

Figure 4 above shows the results from the BEMA question of what direction an electric field would point inside the shaded area to cause this path of travel for the negatively charged particle [4]. This did not exactly have the desired result.

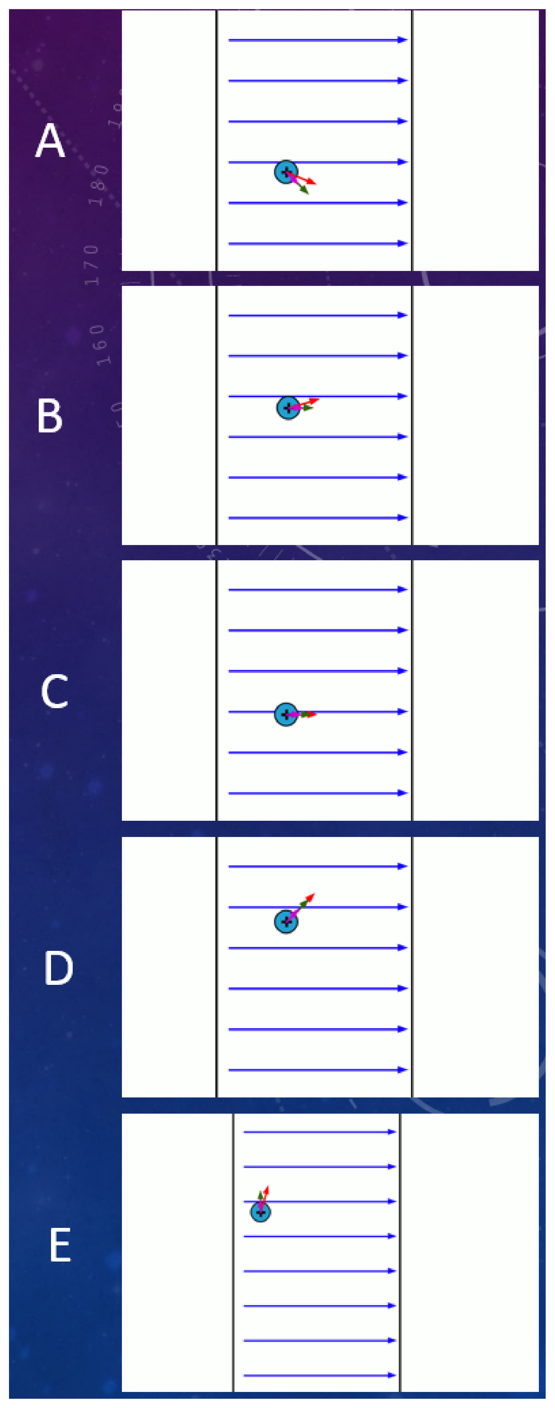

Figure 7. Possible trajectories of a charged particle in an electric field [5].

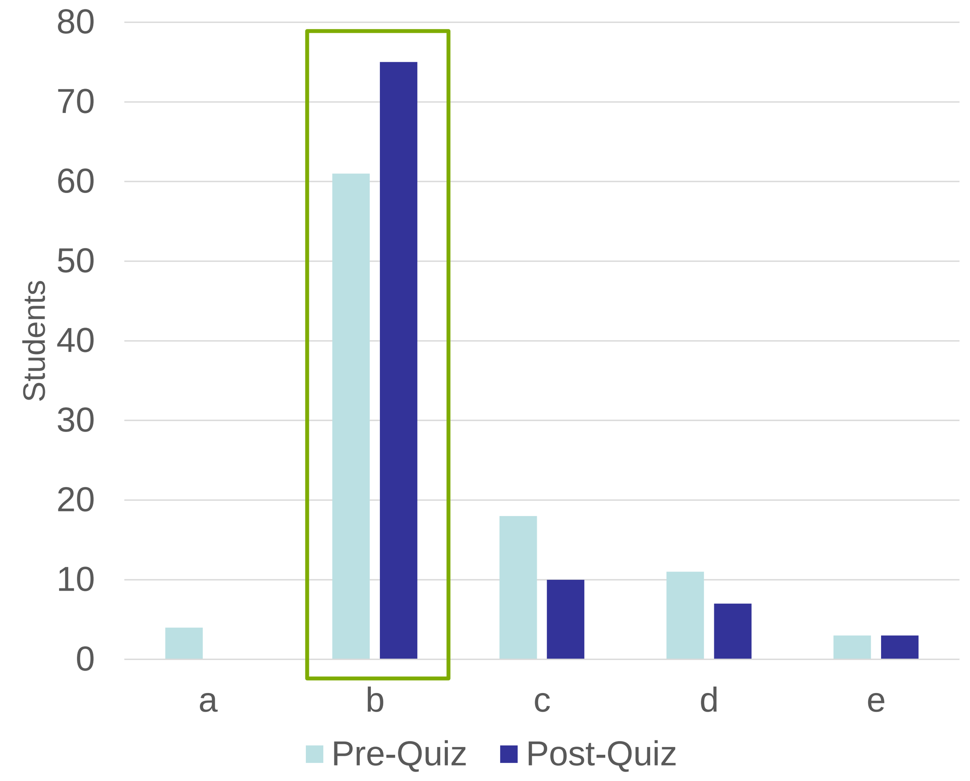

Figure 8. Shows the results of a STEMcoding assessment question that uses animated figures to ask the question of the correct trajectory of a positively charged particle in a constant electric field [5].

Figures 3 and 8 show that the results from animated questions about the behavior of a charged particle yielded the correct answer both before and after completing a STEMcoding activity. The written BEMA questions resulted in more wrong answers than the animated questions.

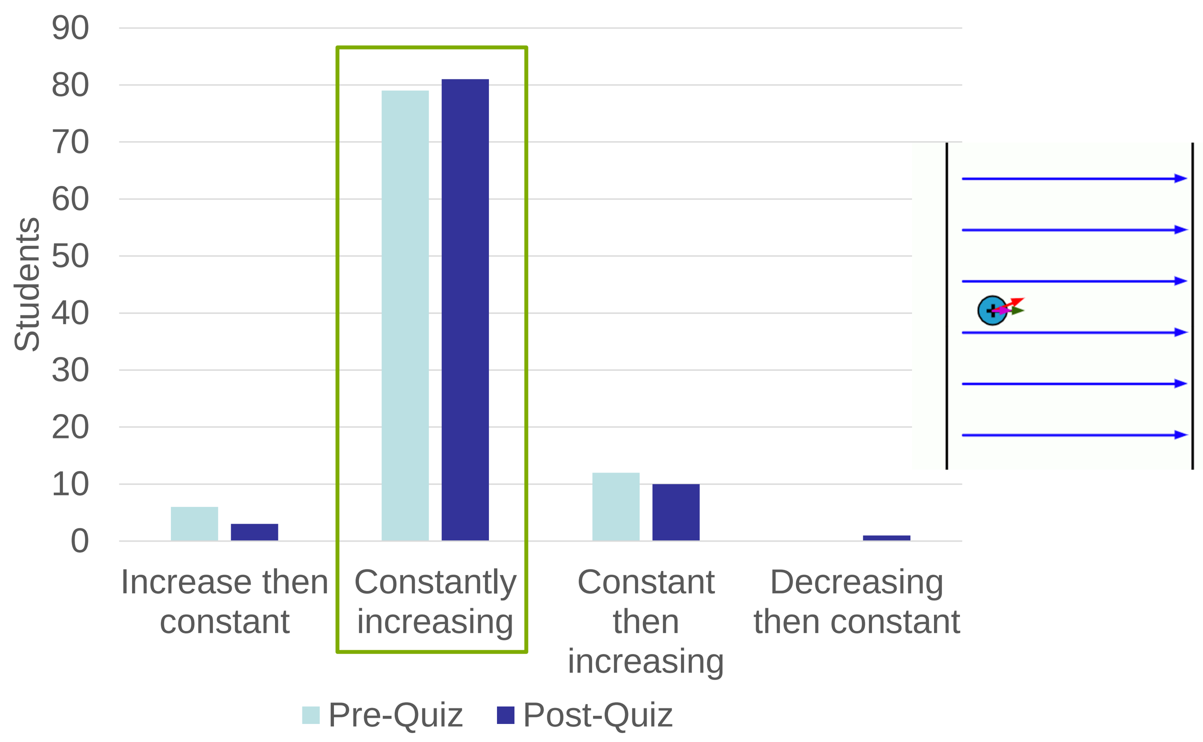

Figure 3 above shows the results of a STEMcoding assessment question for the Particle Accelerator Activity that poses the question: "What is the speed of the particle when it is in the accelerator?" with the correct answer boxed in green [5]. This question utilizes an animation of a charged particle in an electric field.

Conclusions

The STEMcoding Project aims to promote computation thinking and diversity while providing students and teachers access to programming activities and videos. Conducting these programming activities allows students to interact with the physical concepts in a different way and be better prepared for future careers in STEM.

References

1. Orban, C. M., & Teeling-Smith, R. M. (2020). Computational Thinking in Introductory Physics. *The Physics Teacher*, *58*(4), 247–251. doi: 10.1119/1.5145470
2. Orban, C., Porter, C. D., Brecht, N. K., Teeling-Smith, R. M., & Harper, K. A. (2018). A novel approach for using programming exercises in electromagnetism coursework. *2017 Physics Education Research Conference Proceedings*. doi: 10.1119/perc.2017.pr.067
3. Orban, C. M., Teeling-Smith, R. M., Smith, J. R. H., & Porter, C. D. (2018). A hybrid approach for using programming exercises in introductory physics. *American Journal of Physics*, *86*(11), 831–838. doi: 10.1119/1.5058449
4. R. Chabay, B. Sherwood. *Brief Electricity and Magnetism Assessment (BEMA).*
5. STEMcoding. 2019. stemcoding.osu.edu

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