CACHE: Development of Computational-Based Tools and Modules for Chemical Engineering Education

Coding Concepts and Chemical Engineering Analysis With Interactive Jupyter Notebooks

Final Report

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Abstract

This final report summarizes the work completed on the project of creating educational interactive coding notebooks for chemical engineering numerical analysis. The official funding period for this project was January 15, 2020 - January 14, 2021. All proposed tasks have been successfully completed in accordance with the updated project schedule presented in Progress Report 1.

1 Accomplishments

Major Activities The PI and two of his PhD students have completed the design, implementation, class deployment, and final revision of 6 interactive coding notebooks each for MATLAB (Live Editor) and Julia (Jupyter) programming languages. Each of the proposed problem types has been defined as its own learning module with high-level learning objectives and specific educational objectives. For each learning module, at least one example problem has been identified from the chemical engineering literature with emphasis on examples relevant to current industry challenges. A paper was also presented at the AIChE Annual Meeting 2020 as part of the "Computing and Data Science in ChE Education: In Honor of Fred Justice's Contributions to the Education Division".

2 Products

The following interactive coding notebooks have been produced for MATLAB (Live Editor) and Julia (Jupyter) programming languages:

1. Linear algebraic systems with process flowsheets
2. Nonlinear algebraic systems with process flowsheets
3. Ordinary differential equation initial value problems, simulating a dynamic CSTR
4. Ordinary differential equation boundary value problems, simulating steady laminar flow
5. PDE initial boundary value problems, simulating unsteady heat exchange.
6. Optimization, a nonlinear programming model for industrial wastewater treatment.

The presentation "Instructional Videos and Interactive Notebooks for Learning Coding Concepts in Chemical Engineering Analysis" was produced and presented at the AIChE Annual Meeting 2020 (virtual). The presentation can be found here (the PI's research website).

3 Participants

Two of the PI's PhD students actively worked on this project. One was funded by this award and the other worked on aspects complementary of his own project. Active participants:

- PI: Matthew D. Stuber, PhD
- PhD Candidate: Matthew E. Wilhelm (funded on this project)
- PhD Candidate: Chenyu Wang

Undergraduate researchers Talha Bhatti and Megan Walsh provided initial review and feedback prior to deployment in the Fall 2020 class.

4 Spending report

The original budget allocated $312 to the PI's summer salary and the remaining to student support. We have budgeted to support the senior graduate student at approximately 50% over the summer period of 5/23-8/22 amounting to approximately $391/week. At the time of this final report, all funding has been spent.

5 Major Findings and Conclusions

Students found the interactive coding notebooks to be extremely helpful, especially for self-identified "visual learners". The major change in course modality to hybrid/online due to COVID-19 was made easier by offering these materials as additional (optional) interactive learning content. Some student comments received on the teaching evaluations include:

- "I think the interactive notebooks were really helpful in teaching the concepts and basic codes. I also liked how the class was taught very closely to the textbook so I could use that as supplemental material"
- "I think the matlab interactive notebooks were very helpful at giving us an idea of how to actually implement the theory."
- " I feel like with some of the material Professor Stuber made me more confused as opposed to the interactive notebooks, which explained it a lot more clearly."
- "For the large majority of the homework/interactive notebooks, the assignments were understandable and the interactive notebooks did a good job at coaching me through the problem"

The only criticisms received were that the notebooks were not exhaustive homework solutions and that the notebooks could be more helpful if I used them in lecture and stepped through them. As this was the first year offering the notebooks, and this was also a year where the course modality was changed, data mapping notebook interactions to student outcomes is limited. At the highest level, the class as a whole performed almost equally with the previous year's. This was not expected as the hybrid/online modality presents additional challenges to students. When grouping students by whether they interacted with > 3 or ≤ 3 notebooks, the group interacting with the greater number of notebooks performed 22 percentage points higher on average in their final grade than those of the lower category. For each midterm exam, students with more interactions achieved roughly 20 percentage points higher than those of the lower category. Lastly, on the final exam, students who had more interactions achieved 27 percentage points higher than those of the lower category. Even though these are staggering numbers, they are only preliminary and correlation does not imply causation. The interactive notebooks will continue to be offered in future years along with a thorough analysis of how students use them and their overall outcomes.