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Work-in-Progress: Introduction of a Computational TA Role to Support Undergraduate Training in Computational Thinking Strategies for Chemical Engineering Applications

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Introduction

Our ability to solve engineering problems of increasing complexity grows with the increasing availability and power of computational resources. Engineers rely on computational thinking in their approach to modern problems, but training in these skills is a challenge in many engineering programs [1]. Since student experience varies [2], [3], instructors must ensure everyone has the necessary foundational skills but do so in a way that does not take time away from content instruction. Individualized support outside of class through office hours or tutoring can be effective if the TAs have the necessary experience and resources [4]. Other obstacles in the implementation of computational-focused activities in the curriculum include time needed to develop quality course materials, inconsistent use across classes, and faculty preferences regarding various software [5]. When properly implemented with adequate support, computational techniques can improve student performance and motivation in their chemical engineering studies [6] as well as prompt students to transfer such skills to other courses [7].

The present project seeks to develop, implement, and assess a computational support program for undergraduate chemical engineering students to better align course resources with course objectives. This program introduces a computational TA (CTA) to the department to serve two roles: provide one-on-one support for undergraduate students learning to use software for engineering applications, and to collaborate with teaching faculty to develop resources and activities to consistently build skills applicable to course topics. This specific approach with the new CTA role was proposed so as not to require additional responsibilities of traditional course TAs. Further, this role will serve as a connection across various courses in the undergraduate curriculum to promote consistency in objectives and expectations.

Motivation and Methods

This work-in-progress project prioritizes program development for the sophomore-level introductory mass and energy balances course within the undergraduate chemical engineering program before expanding to other classes, and Excel was selected as the program of choice for this introductory engineering course due to its popularity in both industry and academia. Other software will be implemented in subsequent courses as the project progresses.

The departmental learning objectives for the mass and energy balances course include not only content-related skills but also specify that students "use spreadsheets (Excel) and/or an applied mathematical software package to solve material and energy balance problems." Complicated systems of equations requiring a numerical solver provide opportunity to practice these skills, but the complexity of such problems can result in students feeling overwhelmed, especially for students with limited experience using software for problem-solving applications. Among a sample group of students beginning the mass and energy balances course, 27 out of 78 (35%) self-reported needing guidance when using Excel, highlighting the need for additional support for students with limited experience. The CTA role, filled by a graduate student hired for two semesters at a time and supervised by the program lead, was established to bridge the observed computational experience gap through one-on-one support and through course activities that build student confidence and alleviate anxiety towards using numerical methods. The present paper describes the initial implementation and pilot semester of the program.

In addition to holding drop-in office hours for students seeking individualized support, the CTA has collaborated with the course instructor to develop activities related to course content and emphasize specific skills related to problem-solving techniques in Excel. A few examples of the weekly activities included in homework assignments are summarized in Table 1.

Table 1. Sample Excel activities corresponding to specific course topics.

Course topic	Excel Activity	Skill Objective
Unit conversions	Calculate mass and weight in various units and gravitational acceleration constants, where the conversion factors in equations are absolute cell references.	▪ Using basic Excel operations ▪ Distinguishing between relative and absolute cell references
Pressure calculations	Use "CONVERT" function to quickly convert a large number of pressure measurements into several different units.	▪ Using software documentation to find specific details about function implementation (i.e. list of accepted units for the "CONVERT" function) ▪ Interpreting software documentation to determine the required arguments for a function
Mass balances	Use SOLVER add-in to solve a system of equations. Repeat for varying design parameters to observe effects of certain parameters on process production.	▪ Loading/accessing add-ins ▪ Setting up a spreadsheet to numerically solve a system of equations ▪ Understanding basic elements of numerical methods (i.e. minimizing sum of squared errors) ▪ Designing spreadsheets for continued use and adaptability.
Energy balances	Use IF function to design an interactive spreadsheet that calculates enthalpies based on user-selected reference states.	▪ Returning to documentation to find function arguments. ▪ Designing an interactive spreadsheet that accepts user inputs.

These activities were developed with specific intentions. Firstly, these activities begin with basic skills – rather than waiting until problems are complicated enough to necessitate computational techniques, these activities begin with very simple problems that focus on building foundational skills among students with limited experience. This leads to a more seamless transition as problems build in complexity throughout the semester and allows the CTA to address areas of confusion before students are overwhelmed. Secondly, activities are developed for every homework set to demonstrate a variety of applications and to provide repeated exposure and practice of computational thinking skills. As these weekly Excel activities become a regular expectation rather than simply being reserved for only the most challenging problems, student attitudes may shift towards viewing Excel as useful and convenient rather than confusing and complicated.

While the primary responsibility of the CTA is student support, the role supports course instructors as well. The CTA's assistance in the development of course activities lowers the barrier for instructors to incorporate computational thinking strategies in homework assignments. Additionally, this dedicated computational support allows instructors/TAs to focus on course content as it frees them from spending a disproportionate amount time trying to help individual students debug their Excel files, improving course content support.

Program Assessment and Sustainability

The program will be monitored from two perspectives: (1) changes in the attitudes and proficiency of students regarding the software of choice, and (2) perceptions of faculty and TAs on class implementation. The student-focused assessment will be based on student use of CTA office hours and on survey responses. These surveys will be conducted at the start of the semester (Survey A) and late in the semester when students start team-based assignments (Survey B) – this timing was selected to monitor whether students felt prepared to work with their team. Survey question topics and the corresponding program objective measured are provided in Table 2. Because the program seeks to not only promote computational skills but also to lessen student reluctance to use these tools, survey questions related to student attitudes are also included.

Table 2: Survey question topics (and an example question) with corresponding objective.

Survey question topic	Program Objective
Technology and software availability "For software required in courses, do you typically install it on a personal device, or do you use university resources like a library computer?"	Determine common technology usage and identify gaps in accessibility among undergraduate students.
Self-reported general competency level "Choose the option that best describes your experience level with Excel."	Increase in self-reported competency level for the software of focus for the given course.
Perception of usefulness of computational methods of solving systems of equations "Have you used (or heard of) Solver in Excel, and what are your opinions of it?"	Increase the number of students familiar with Solver (or similar) and that perceive it to be useful in engineering applications.
Student attitudes towards computational tools "Indicate whether each of the following statements applies to you: ▪ I feel confident using computational tools to solve equations. ▪ When I have an error in Excel, I am not sure how to figure out what caused the error. ▪ Etc."	Reduce anxiety and hesitancy in learning new tools even with limited background; develop basic skills in reading documentation and troubleshooting errors; increase confidence in learning new tools in engineering settings.

While these surveys measure whether program objectives are met, they also serve as a measure of need. These surveys will be administered each semester to monitor student needs over time so the program may adapt accordingly.

The faculty-focused assessment is conducted in the form of regularly scheduled meetings to promote continued collaboration and communication between the CTA and course instructors. This ensures that developed activities meet the needs and course learning objectives, fulfill the

instructor's preferences for assignment format, and are adequately supported by the CTA. These activities are made accessible to all instructors for continued use, feedback, and updates.
To ensure the sustainability of the program, experienced CTAs will update training resources and help train new CTAs. A centralized repository of resources, including troubleshooting tips for common issues, summary guides for common methods/concepts, and consolidated lists of additional university-provided resources are made available to all CTAs and instructors.

Preliminary results

Survey results presented below indicate small but positive changes in student-reported confidence in computational skills. It is important to note, however, that because this semester a pilot semester focused on the logistical implementation of the program and only concerned with improving learning outcomes in one specific course, a formalized review was not conducted. Instead, informal surveys – entirely voluntary – were conducted anonymously with no personal data collected. Consequently, the number of student responses differed (78 Survey A responses and 60 Survey B responses) and Survey A and B responses are not matched. Additionally, while these results may indicate learning outcomes of the course itself, they cannot imply that any effects were due to the computational support program; this type of data from semesters prior to program implementation does not exist, so program impact may be assessed via observations by faculty and TAs involved in the course both before and after program implementation. For these reasons, formal statistical analyses and significance testing are not included. Future work will include a more detailed program review.

As illustrated in Figure 1, the fraction of students reporting they have some experience and are comfortable using Excel increased. Interestingly, however, the fraction of students claiming to have a lot of experience decreased. This may simply be because some of the students initially reporting extensive experience did not fill out Survey B, or this result may be due to students being exposed to a variety of applications of Excel throughout the course and realizing there is a great number of functions they have not yet learned.

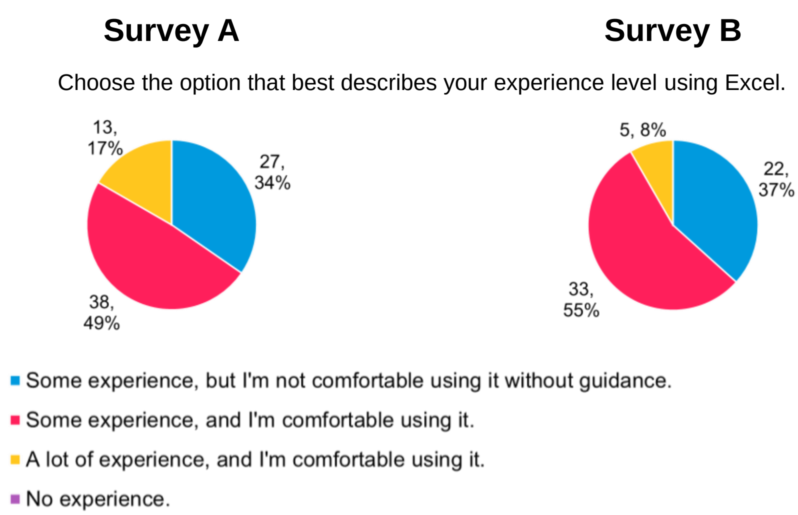

Figure 1. Student responses regarding Excel experience from Survey A, given at the start of a mass and energy balances course (n=78), and from Survey B, given towards the end of the semester (n=60).

The Excel add-in Solver is a readily available tool to numerically solve systems of equations and consequently was emphasized throughout the course. Encouragingly, the number of students who report knowing how to use Solver and believing it to be useful increased drastically, as shown in Figure 2.

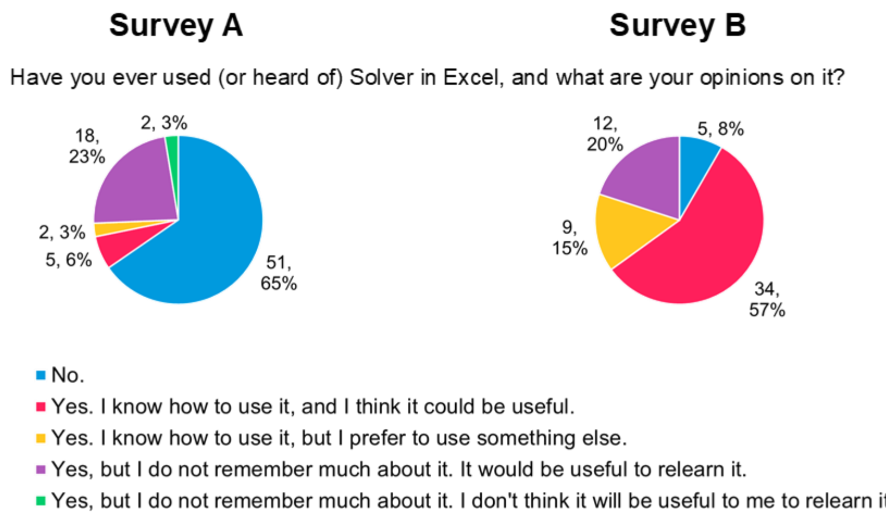

Figure 2. Student responses regarding Solver from Survey A, given at the start of a mass and energy balances course (n=78), and from Survey B, given towards the end of the semester (n=60).

Many of the student-reported attitudes also showed small but positive changes, as illustrated in Figure 3. The fraction of students indicating that they feel confident using computational tools to solve equations increased, as did the fraction indicating they can read and understand software documentation. Additionally, students appear to have learned how to better organize their problem setups as indicated by the decrease in the fraction of students reporting that setting up problems in Excel is more complicated than if they had done so on paper. These results, however, also indicate that hesitancy to use software and difficulty in troubleshooting errors remain areas of concern and should be prioritized in the following semesters.

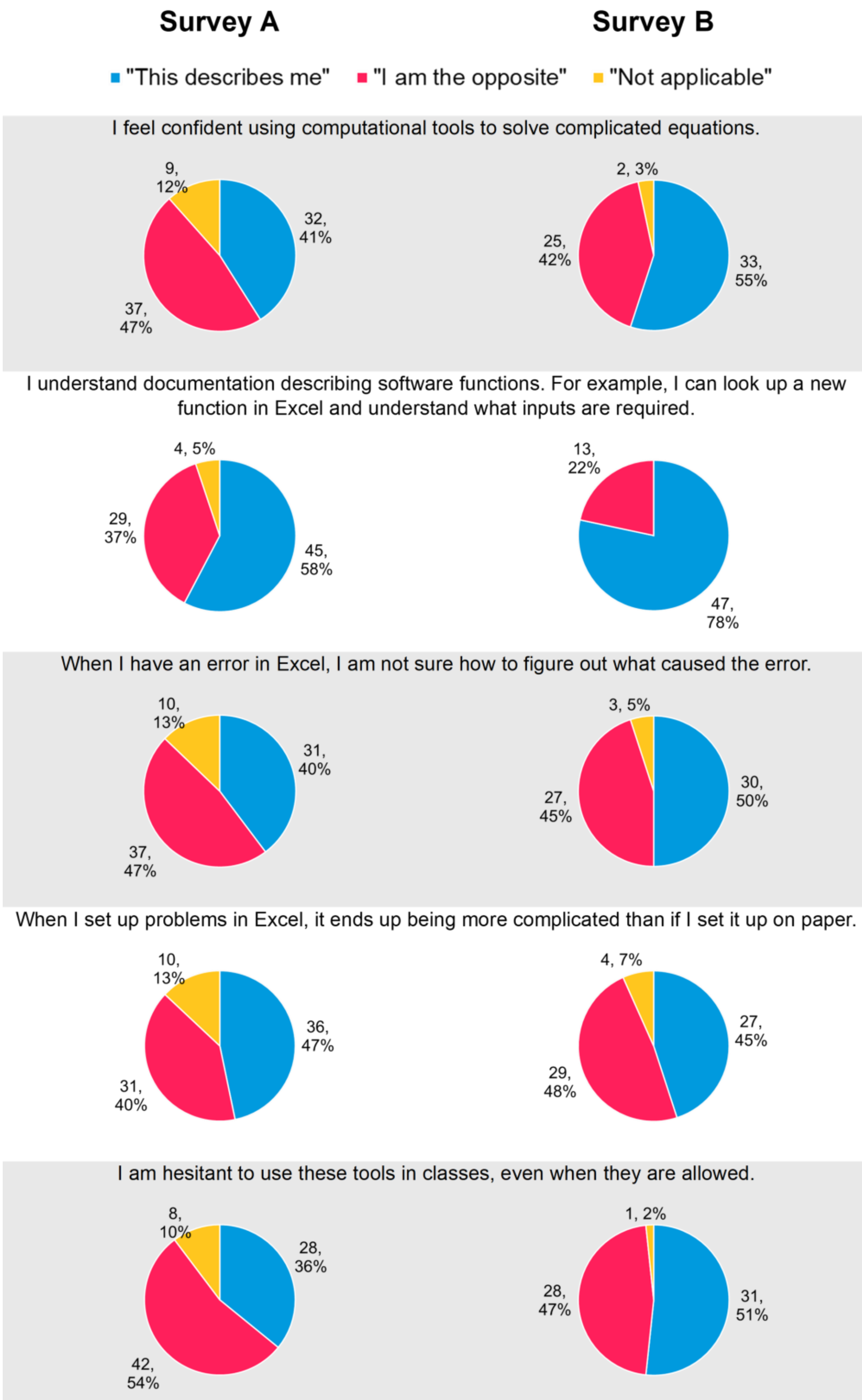

Figure 3. Student responses regarding attitudes towards computational tools from Survey A, given at the start of a mass and energy balances course (n=78), and from Survey B, given towards the end of the semester (n=60).

Student perception of having dedicated Excel office hours was positive despite low attendance in these help sessions. Only 6 out of 60 students reported occasionally or frequently attending the Excel office hours, and 7 additional students reported asking the CTA questions about Excel during his regular course office hours. Yet when asked to indicate which course resources were helpful, Excel office hours were ranked favorably, indicating students appreciate the availability of the resource when needed. To improve attendance, CTAs may try to increase communications regarding the office hours schedule or switch to scheduling office hours on an as-needed basis to better fit student schedules.

Conclusions and Future Work

Although the necessity of computational thinking skills in engineering applications continues to grow, student experience using computational tools varies. To improve instruction and available of resources surrounding computational tools, class materials for an introductory mass and energy balances course have been developed, including homework problems to correspond with course topics that build Excel skills from very basic operations to more advanced interactive spreadsheets. To ensure students with limited experience have appropriate resources and support, these activities are being implemented with an additional teaching assistant dedicated to computational support. Following the conclusion of the pilot class, feedback from both students and faculty will be collected to assess the program and improve the course. Preliminary results from the pilot semester indicate positive changes in student confidence and attitudes, but hesitancy and difficulty troubleshooting errors remain. The program seeks to provide the consistent support and ongoing practice needed to build computational confidence, empowering students of all experience levels to embrace the challenges of an engineering education and career.

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