ACS Grants Program: Final Report Form

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Host Institution: Washington and Lee University
Project Title: Pre-Chemistry Tutorial System
Today's Date: 1/10/2020

1. Project summary

The purpose of our project was to generate an online tutorial system to help students transition from high school level math and chemistry to college level math and chemistry. Other online math and chemistry tutorial systems exist, but available free versions do not contain chemistry practice problems. Since practice and retrieval of information are critical for learning, these systems are suboptimal. Additionally, available online tutorial systems are certainly not tailored to the institutions supported by this grant, W&L and Rollins College. Our goal was and still is to help low socioeconomic status (SES) students transition successfully to college. This is a serious challenge in STEM disciplines that have low retention rates generally, but especially among low SES students.

In our proposal, we demonstrated an early prototype of our online tutorial system, named ChemTutor. The system was at an early stage of development but contained some working modules that would appear in the final version. Our goal for the grant period was to launch ChemTutor for entering students at W&L and Rollins by the end of the summer and to assess the success of ChemTutor in the fall of 2019. You can view the public portions of our released web application at https://chemtutor.academic.wlu.edu. For completeness, selected screenshots of ChemTutor can be found in Appendix A.

Our original timeline from the full proposal is below:

Time	Task	Leads
Winter	Video content development	Desjardins, Riley
	Numerical and topical practice exercise development	Friend
Spring	Design, implementation of web application: • recording usage data for assessment • registration, login functionality • feedback/progress for students • graphing exercises	Sprenkle, Friend

	Video content development	Desjardins, Riley
Summer	Baseline assessment	Riley
	Development/integration of additional practice exercises Web application refinement, bug fixes	Sprenkle, Friend
	Video content refinement, integration into Wordpress site	Desjardins, Riley
	Student alpha testing, feedback Further web application refinement, bug fixes	Sprenkle, Friend
	Release application to all W&L and Rollins students for use	
Fall	Assessment	Friend, Riley

2. Attainment of goals

The timeline shown above served as a guiding document for the development and release of ChemTutor. At each stage, we met our self-imposed deadlines for listed tasks. Throughout the winter of 2019, we held monthly meetings to organize modules for the web application and to schedule module development. Video content was prioritized early in the granting period, culminating with the creation of 22 separate video tutorials. Practice problem development occurred later so that practice problems would integrate well with video content. In the spring and summer, Friend and Sprenkle met routinely to discuss development of the web application, and Sprenkle integrated ChemTutor development into a course on web applications. The web application was released for alpha testing in late June, and bug fixes were completed throughout July. During the summer, we also created individual videos where the chemistry faculty associated with the project spoke about their personal journeys in chemistry. The ChemTutor web application was finalized and released to entering students at W&L and Rollins in August 2019. Minor technical issues were handled in real time as they arose. Data were collected at both Rollins and W&L for assessment purposes in fall 2019, and these were compiled by the Director of Institutional Research at Rollins and the Senior Advisor to the President for Strategic Analysis at W&L. Detailed information on outcomes is below (Impact of project). In summary, during the granting period, a functioning web application with 5 modules containing 15 problem sets was developed, tested, and released at Rollins and W&L.

3. Impact of project

ChemTutor made a meaningful impact on student success for those who used the application. Participation rates were much higher at Rollins compared to W&L, perhaps due to the late registration date at W&L (which occurs immediately prior to class). At W&L, only four students used ChemTutor prior to taking CHEM 110 (General Chemistry). For these four students, they attained higher pre-test chemical knowledge scores compared to their 33 peers (27.0% vs. 25.25%), and more importantly, they achieved higher gains over the course of the semester (13.0%

improvement vs. 11.25%). These sample sizes are far too small to make meaningful conclusions, and it is clear that engagement with the web application must be a priority in the future. CHEM 110 is also taught in the second semester at W&L, and in that case, instructors have emailed enrolled students to encourage them to use ChemTutor. We are optimistic that additional students will use the site next term.

All students enrolled in CHM 120 at Rollins were encouraged (but not required) to make accounts with ChemTutor, and 50% of 116 students obliged. In total, 26% of Rollins CHM 120 students chose to interact with the ChemTutor application two or more times between August and October 2019. The incoming math abilities of the students who opted to use ChemTutor were not significantly different than those who did not. The students who opted to use ChemTutor averaged 75% on the math pre-test, and students who did not interact with ChemTutor at least twice earned an average math pre-test score of 82%; these differences did not reach statistical significance with a student's t-test ($P = 0.4$). However, on average, students who used ChemTutor two or more times completed CHM 120 with a significantly higher GPA than those who did not (2.12 compared to 1.41 on a 4.0 scale, $P = 0.01$). These preliminary data are promising enough to warrant continued use and expansion of the system. The limited sample size did not allow for demographic analyses without the risk of identifying individuals.

Consistent with the principles of universal design, we were pleased that this system was available to any student who felt they needed the extra support, regardless of demonstrated need that may have been defined arbitrarily. Indeed, it is limiting to assess a student's academic preparedness for chemistry with a simple algebra exam when other factors such as reading comprehension, mindset, and grit together affect student performance. Qualitatively, students reported gratitude for the application and its ease of use and also expressed a desire for additional videos and practice problems. A few ($n = 9$) students relied on ChemTutor regularly throughout the term (up to 39 times), not just in pre-term preparation. The CHM 120 professors reported that it was a relief to have, for the first time, a customized resource to which they could refer students who were struggling early in the semester. Thus, the program has utility both as a pre-college preparatory program and, somewhat unexpectedly, during the course.

4. Consortial (ACS-wide) value of the project

We deliberately made ChemTutor moderate in scope and release to increase the likelihood of a smooth and timely rollout, which we believe we achieved. With these promising results, we can make ChemTutor available to other institutions. However, the application is not yet "plug-and-play" and requires more work to remove barriers to uptake at other ACS institutions (see Next Steps). This is a major focus of our current efforts. We are examining and modifying the architecture of the web application to facilitate transfer to other institutions.

ChemTutor has been robust since its initial release making it sustainable. After the site launched, very few help tickets were submitted, which mostly had to do with account creation and not fundamental issues with the site itself. After these initial concerns, the site was maintained with minimal effort.

5. Lessons Learned

The first surprise, evident from the genesis of the project, was how two different ACS colleges could be struggling with the same challenges and agree on the same intervention. Our communication was efficient, and we found it pleasant and facile to come to a consensus on the details of the project. This translated into productivity and the smooth rollout. Setting stringent yet attainable deadlines running the length of the granting period and establishing clear division of responsibilities was critical. Scheduling in a reasonable alpha testing period and having good ongoing communication between Rollins and W&L to address bugs was similarly useful.

The thoughtful development of micro-lectures, such as those embedded into ChemTutor, requires great time and attention to detail. While we were all grateful to have had the impetus to dig into this software, we wish we had more time to polish and refine video content.

Statistical analyses that are necessary to confirm the effectiveness of an intervention such as ChemTutor are especially challenging at smaller colleges. Taking into account diversity in any form or a short timeline (one year) and an "opt-in" approach further limits data analysis. Ongoing efforts at both Rollins and W&L are required to determine whether ChemTutor is helping our target group, low SES and URM students, effectively, but these efforts will continue.

Rollins was required to change their pre-course assessment when the College Board discontinued the Diagnostic Elementary Algebra exam between 2018 and 2019. This necessitated the piloting of an unvalidated algebra pre-test exam this year.

Lastly, we were surprised at the low level of uptake at W&L. Clearly, additional efforts are required to promote the software. Steps are being taken for the winter semester's offering of General Chemistry with professors encouraging students to use the site. Reaching out to students in the summer is going to require more effort since students at W&L do not enroll in courses until a few days before the start of the term. We plan to work with student affairs to further promote the software.

6. Next Steps

This ACS project coincided with a critical time of demographic shift within the Rollins and W&L student bodies. Rollins is uniquely positioned as a comprehensive liberal arts college in the economically growing, highly diverse Orlando metropolitan area. Rollins now hosts 2,133 traditional undergraduates, 31% of whom are domestic students of color and 21% of whom are Pell-eligible. Rollins is also nearing federal classification as a Hispanic-serving institution (19%). Over the past five years, the number of URM students in CHM 120 has nearly doubled (23 to 42%). W&L is undergoing similar, if less extensive, demographic shifts. The 2019 entering class was 18.4% URM, up from 11.8% in 2015. Pell-eligible student numbers have similarly increased. With these increases in diversity comes increasingly diverse pre-college preparation and an enormous need to serve STEM students, ~25% of each incoming class. At Rollins, because of the success of ChemTutor two junior faculty members in chemistry, both of whom identify as URMs, expressed interest in recording additional content for the site, and all five CHM 120 instructors plan to continue to ask students to use the application as preparation for our fall courses.

The greatest challenge with deploying ChemTutor, brought to particular light in the W&L data, is getting students with greatest need to engage with the software. At W&L, engagement overall was very low, and the site must be advertised more extensively. Among those who created an account, only half used the site more than once. At Rollins, we did not see a correlation between performance on our incoming math assessment, which is a predictor of need for supplemental instruction and use of the ChemTutor program. Furthermore, only half of the students who initially created an account on the application chose to use it multiple times. Obtaining qualitative student feedback regarding why they did not opt to use the program may help influence future design changes and evolution of the application.

The data acquired from this ACS grant are now being used by a team led by Riley to support Rollins' application to the HHMI Inclusive Excellence institutional STEM grant this January. The outcomes of this ACS project also inspired the entire Rollins Chemistry Department to hold a retreat in May to focus on introductory chemistry content, curriculum, and pedagogy.

Perhaps our biggest next step is making ChemTutor available to other institutions. Throughout development, we tried to make the application easily customizable by non-technical users. However, there are still pieces that benefit from technical experience, generating hurdles to wide, external deployment. The application requires a web server, a web application server, a Java server, a Python application, and a database. We have automated scripts to ease deployment on our server, but these are not necessarily portable. Furthermore, wedding parts of the web application with the Wordpress site is another place that cannot be automated, and we will need to create a user-friendly interface to improve usability and multi-year maintainability.

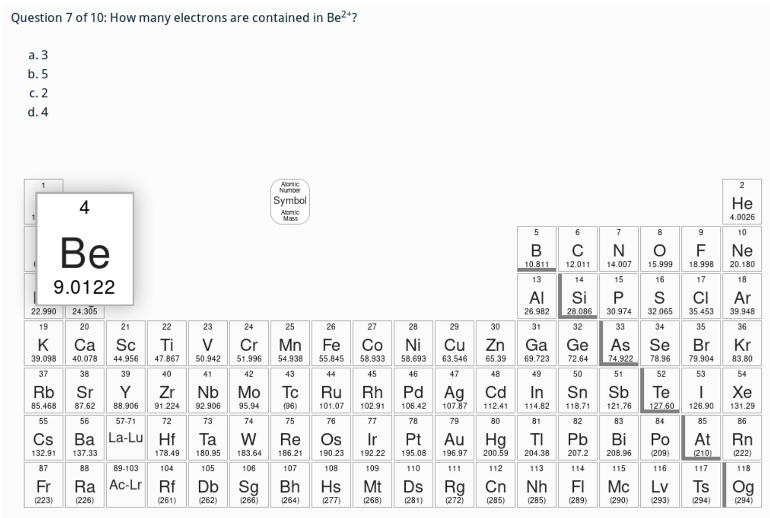
In summary, challenges remain, but we are committed to refining and maintaining the web application in future and transferring ChemTutor to other ACS institutions.

7. Feedback/suggestions for the ACS grant program (optional)

Appendix

While not part of the official final report, the screenshots that follow show some of the features that have been developed as part of ChemTutor.

Since the periodic table is a useful resource to answer a variety of problems in chemistry, we developed a simple, responsive periodic table that students can view on a variety of devices. When a student clicks on an element, the element enlarges for easier reading:



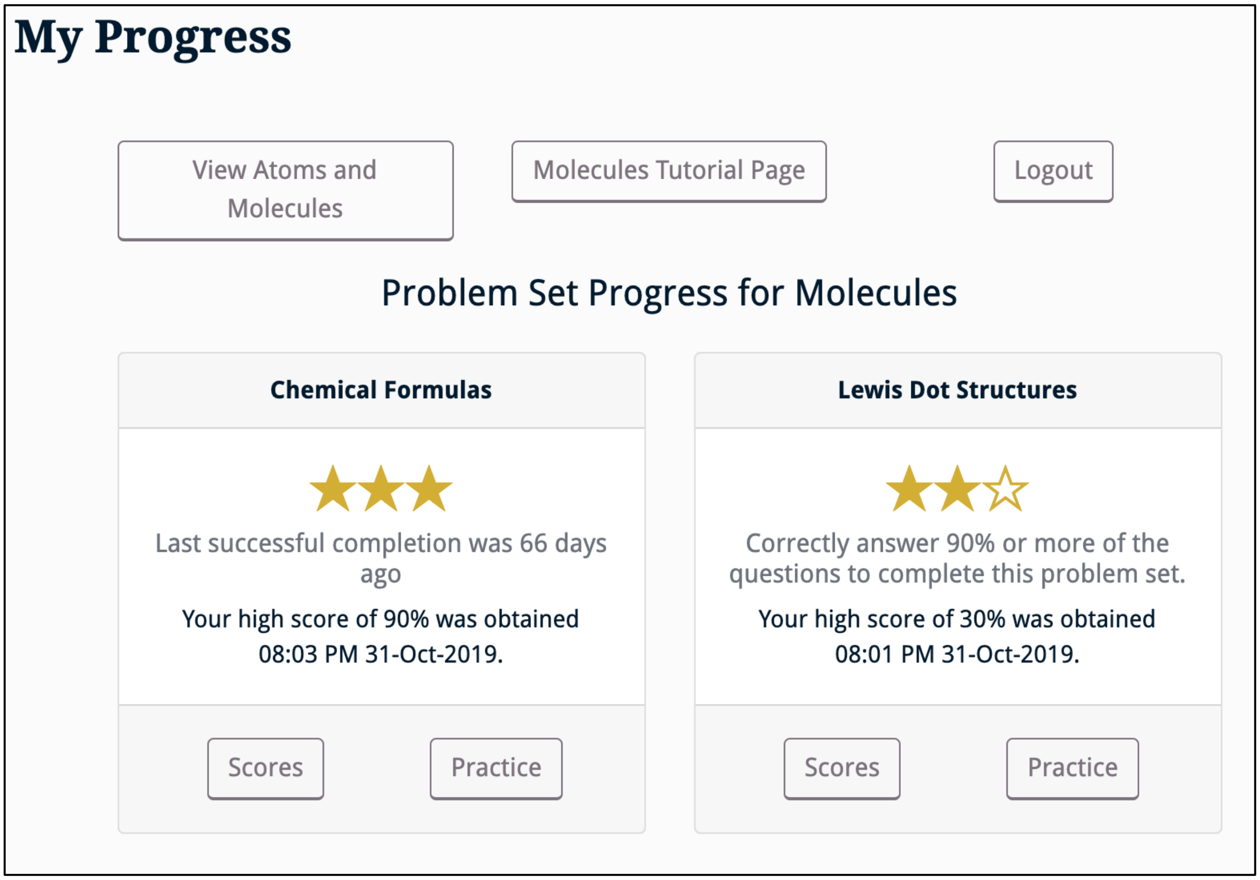
After practicing a problem set, a student will see their answers as well as the correct answers. Note that, since the problems are dynamically generated, students can retake a problem set many times and never get a repeated question.

You attempted 5 questions, of which you got 3 correct.

Check over your answers:

Question	Correct Answer	Your Answer
A reaction has a theoretical yield of 76.3 g, but only 67.5 g were obtained. What is the percent yield for the reaction?	88.5 %	88.5 % ✔
A reaction has a theoretical yield of 22.3 g, but the percent yield is 71.1 %. What is the actual yield for the reaction?	15.9 g	56.0 g ✖
A reaction has a theoretical yield of 29.0 g, but only 27.9 g were obtained. What is the percent yield for the reaction?	96.2 %	96.2 % ✔

Students can see what problem sets they have successfully completed (90% or higher correct answers) and where they should focus their practice. In the screenshot below, the student successfully completed "Chemical Formulas" but needs to practice "Lewis Dot Structures" within the Molecules module.



Students can see their progress on the modules — a level above the problem sets. For example, in the following screenshot, the student has one more problem set in the "Molecules" module (as was shown in the previous screenshot) and one more problem set in the "Intro to the periodic table, isotopes" module to complete.