Opening the Gate for STEM: WeBWork and OER in the Colorado Community College System

Institution: Colorado Community College System

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Abstract: Colorado Community College System (CCCS) is dedicated to furthering student success through the adoption, adaption, and creation of open educational resources to reduce the cost of course materials and promote equity in the education of our students. However, students enrolled in science, technology, engineering, and math (STEM) classes are often not the beneficiaries of these no-cost resources as many traditional, proprietary STEM textbooks also provide access to homework platforms via access codes associated with the textbook material. This case study will outline the specific challenges surrounding OER implementation in STEM disciplines and detail the efforts CCCS has made to alleviate this issue in its member institutions and Colorado Online @. Particularly, this case study will describe the funding, implementation, and expansion of the open homework platform WeBWorK into the math courses of many of the member institutions in the Colorado Community College System. The case study also describes the successful partnership of institutional faculty and the Colorado Community College System's library that allowed for the development of STEM OER across multiple CCCS institutions.

About Colorado Community College System and CCCOnline

The Colorado Community College System is comprised of thirteen community colleges spanning thirty-five locations throughout the state of Colorado. The system serves over 114,000 students and provides concurrent enrollment, Career and Technical Education (CTE), certificate programs, transfer programs, associate, and bachelor's degrees. CCCS is the largest system of higher education in the state of Colorado and over 70% of CCCS students receive some sort of financial aid.

Colorado Online @ (formerly CCCOnline) is an online consortium of the thirteen colleges in the Colorado Community College System (CCCS). Through the CCCS

colleges, Colorado Online @ provides online courses taught by both member institution faculty and Colorado Online @ faculty. CCCS member institutions and Colorado Online @ offer regionally accredited degrees and certificates in various disciplines. CCCS colleges are regionally accredited by the Higher Learning Commission of the North Central Association of Colleges and Schools. Colorado Online @ develops courses using subject matter and technology experts and instructional designers. These courses are then offered 100% online through the learning management system.

CCCS's Commitment to Open Educational Resources

The Colorado Community College System's mission statement highlights the system's focus on creating an "accessible, responsive learning environment where our students can achieve their educational, professional, and personal goals in an atmosphere that embraces academic excellence, diversity and innovation". The system and the thirteen member colleges' commitment to using and developing open educational resources (OERs) to facilitate equity for students is a direct result of these stated goals. Our student population is unique in Colorado in its breadth and depth. CCCS's thirteen member colleges and Colorado Online @ serve a diverse student population with varying needs based on location, program, socioeconomic level, education level, and educational goals. Facilitating OER development, adoption, and adaption allows CCCS to eliminate a financial obstacle for many community college students in Colorado and achieve CCCS's goal of creating educational opportunities without barriers for all our students. To date, CCCS and its member institutions have developed more than 210 zero-textbook cost (ZTC) courses.

CCCS acts as a consortium for its member colleges and currently supports work in open educational resources in several ways. CCCS hosts and manages a Pressbooks library for instructors and faculty from all member colleges to upload OER course materials that they have created themselves or previously created materials from others that they want to adapt for their specific classroom contexts. CCCS also hosts an institutional Learning Repository where instructors, faculty, and staff can upload created materials for perusal or use by other instructors within the system. CCCS and Colorado Online @ also provide OER curations, recommendations, and ready-to-teach course shells for instructors. The system office facilitates a system wide OER committee to promote and coordinate OER efforts at individual colleges, across the system, and at the state level. Finally, CCCS provides leadership and

grant support for OER efforts at the institution level and at the system level to fund and facilitate OER projects that promote equity at the student, practitioner, and leadership levels in the CCCS organization.

Open Educational Resources, STEM, and Equity

Open educational resources and the movement towards open scholarship in general has worked to eliminate some of the financial barriers that exist in higher education by allowing students and researchers to freely access information and course materials in a variety of contexts across many different disciplines. Unfortunately, one area where OER development has seen a lag is in courses falling under the science, technology, engineering, and mathematics (STEM) umbrella. On average, STEM course materials and textbooks cost more than other disciplines' course materials, and OER textbook adoption and creation has not been as widespread as OER development in the humanities due to several factors. STEM textbooks and course materials can take more time and effort to produce than textbooks in other disciplines. This is because producing a textbook or course materials for STEM disciplines often requires the development of detailed charts, graphs, technical images, property tables, and thousands of practice problems (d'Entremont, 2021; Gans, 2019). These practice problems are then often reproduced in a homework platform that accompanies the purchased textbook. This homework platform is the primary way students complete assignments for class. The homework platform can be included in the proprietary textbook cost or can be extra depending on the textbook publisher. Both the production of the textbook itself and the development and use of the accompanying homework platform make these proprietary STEM course materials more expensive.

While OER textbooks for community college level STEM classes exist, the core issue surrounding OER textbook use over traditional proprietary textbooks becomes that of the online homework platform. Both students and instructors prefer using online homework platforms for STEM assignments; students enjoy the instant feedback and guidance on how to solve the problems provided by a homework platform, and instructors do not have to dedicate time to grading these homework assignments by hand. Students can also come to class with issues they encounter in the homework if they do not understand the explanation given by the homework platform itself, as they have already identified issues in their conceptual understanding. While homework and assessment can be assigned using the learning management system (LMS) provided by the institution, typically the

grading system for homework or quizzes in LMS platforms provides only a simple "right" or "wrong", unless the instructor has done the extra work for each problem and provided an explanation with every solution. Homework platforms provided by proprietary course materials (e.g. Pearson's My Math Lab, or McGraw Hill's Connect Math) come with this ready-made work, thus allowing the instructor to use this time for other duties.

The additional textbook costs associated with STEM course materials affect student class choice and make it less likely that students will explore STEM degrees and fields if, like many CCCS student, they are struggling financially in other areas of their lives (Martin et. al., 2016). This also means that the relatively higher textbook and course materials costs in STEM disciplines effectively works as a gatekeeping device for historically underserved student populations, as these populations are the most likely to be burdened by higher textbook costs (Jenkins et. al., 2020). Additionally, if students do not have access to the textbook and homework platform on the first day of class due to the cost of materials, they start out behind on classwork and face an uphill battle for success in the STEM classroom.

These issues surrounding materials cost in STEM classes therefore present an equity issue for CCCS students. While both students and instructors in STEM disciplines effectively use the format provided by traditional textbooks with accompanying homework platforms, they remain very expensive. Textbooks and their accompanying homework platforms required for STEM classes in CCCS can range anywhere from fifty to two hundred dollars in addition to tuition costs. CCCS is made up of a large and diverse student body, many of whom are traditionally underserved in higher education and are impacted the most by high textbook costs. In 2022, 38% of CCCS students are Students of Color; 58% of our students are female; and 59% of our students are under 25 years old. Of the 111,000+ students enrolled part-time or full-time at a CCCS institution, 70% receive a form of financial aid (CCCS Facts and Figures, 2023). According to the #RealCollege Survey of CCCS students conducted in 2021, 63% of CCCS students experienced some sort of basic needs insecurity (defined as food insecurity, housing insecurity, or homelessness) (The Hope Center, 2021). Even if students do not want to pursue a major in STEM, almost every program offered at CCCS institutions requires a math course of some sort. This makes the problem of high-cost course materials for math classes a particular burden for many, if not most, CCCS students.

Objective, Process, Data, and Methodology

In 2017, James Morski, a math professor and now the head of the math department at Community College of Denver (a CCCS member institution) started looking into OER to alleviate some of the textbook cost burden from his students. He knew of several reputable zero-cost math textbooks, but they did not also come with an online homework platform or practice problems. As previously stated, both students and instructors prefer using an online homework platform for a variety of beneficial reasons. While examining the different options for no-cost or low-cost math homework platforms, he discovered a colleague at a different CCCS institution was working on the same problem. Brenda Forland, a math professor at Red Rocks Community College (a CCCS member institution as well), was looking into using the open-source and no-cost homework platform WeBWorK in some of her classes to address the textbook and homework platform cost issue. Forland and Morski began to work together in order to come up with a program that would benefit their students at both institutions using WeBWork.

What is WebWork?

WeBWork is an open-source homework platform developed in 1996 for STEM instruction and problem practice by Professors Michael Gage and Arnold Pizer in the mathematics department of the University of Rochester. It was expanded in 2009 with the help of the Mathematics Association of America to disseminate the use of WeBWork to more educational institutions around the globe. Currently, over thirteen hundred intuitions use WeBWork for STEM instruction. WeBWork is an open-source homework platfrom where users can author their own questions using Problem Generation (PG), a Perl-based programming language. WeBWorK also comes with an Open Problem Library with over 35,000 unique pre-authored practice problems from across STEM disciplines that are available to anyone using the software ("The WeBWorK Project", 2023). The ability to author one's own question set tailored for a particular instructor's class presented a useful and interesting feature to both Forland and Morski, however, this functionality presented a steep learning curve. Instructors would have to code all homework problems by hand, necessitating a large amount of work on the front end of developing a course. Forland and Morski wanted to use WeBWork as a zero-cost homework platform in order to address the math course material cost inequity for their students but needed additional funding and support to initiate the project.

Grants and Funding: Timeline and Coordination

Grant 1: CCCS Innovation Grant, 2017

Forland and Morski knew bringing this project to fruition was going to take a significant amount of time and labor to complete. Therefore, the pair looked to the Colorado Community College System office for assistance on how to fund this extra effort. They subsequently applied for and won $93,500 through the CCCS Innovation Grant to fund their WeBWorK proposal. This proposal included developing and implementing pilot programs at Red Rocks Community College, Community College of Denver, and CCCOnline (now Colorado Online @) using WeBWorK as a zero-cost homework platform for College Algebra (MAT 121) classes at these instructions. College Algebra was selected as the class for the pilot program as it is the math class taken by the most students each semester and could a provide a reasonable baseline for implementation. If successful, it would also have the most significant impact to lessen the largest number of students' course material costs.

CCCS provided the funding for the project through awarding the Innovation Grant and provided necessary technology infrastructure support as well. CCCOnline's Academic Technology department hosted WeBWorK on a server for all three institutions involved in the pilot in order to minimize barriers to collaboration. CCCOnline hosting and administrating the server for the pilot ensured that all parties could collaborate on authorship of the problems for the college algebra in WeBWorK. With this support, Morski and Forland were able to offer training workshops for those interested in supporting the project in their own institutions. After this training, this first group of math professors was able to successfully code homework problems from scratch in WeBWorK to support the college algebra classes at Red Rocks Community College, Community College of Denver, and CCCOnline over the summer of 2017 to be tested in Fall 2017 and Spring 2018.

To measure the results, Morski and Forland compared the students' scores from the sections using WeBWorK as the homework platform to the sections using the proprietary homework platform on both the final exam and the final grades in the class after each of the 2017 semesters. There was no significant difference in student success when comparing the performance of the two groups of class sections, so WeBWorK was determined to be a viable solution for creating zero-textbook cost college algebra classes. This success also opened the door for

WeBWorK to be developed as a homework program for math classes offered across the CCCS system.

Grant #2: Colorado Department of Higher Education Open Educational Resources Grant-- WeBWorK Consortium: A Collaborative Data Source for Math Instruction, 2019-2020

After the success of the pilot program, Morski and Forland approached Brittany Dudek, the Director of Library and OER Services for the Colorado Community College System, about obtaining more funding to expand the project to other CCCS institutions. Dudek, Morski, and Forland applied for and won $74,800 from the Colorado Department of Higher Education's (CDHE) Open Educational Resources Grant to continue the development and implementation of WeBWorK across the CCCS system. All work and resources developed under this grant are licensed with a CC BY NC Creative Commons license, per the grant's requirements.

The goals of the new grant funding were threefold. Firstly, Morski and Forland would be the subject matter experts (SMEs) regarding WeBWorK implementation at each of the other institutions in CCCS. To this effect, they created training materials and documentation for others interested in working with the program. Using these materials and expertise, they created a WeBWorK liaison model to spread their knowledge to the other CCCS institutions. These liaisons (self-identified as interested in taking on this responsibility at their home institutions) received a stipend to attend a training led by Morski and Forland on using WeBWorK and incorporating previously developed math course materials to support their math programs. The original training was conceived as an in-person event at the CCCS campus, but due to the onset of the COVID-19 pandemic in early 2020, Morksi and Forland were able to pivot to an online training format.

These liaisons were designed to be the point-of-contact for their campuses and departments regarding using WebWorK and integrating the previously designed math course materials successfully. The liaisons are responsible for overseeing the automated course creation process and for copying problem sets into course shells in D2L. This liaison model ensured that most problems students or instructors encounter while using these course materials can be handled at the campus level and provide stakeholders with more timely and targeted troubleshooting.

Secondly, this grant provided for the dispersal of minigrants to interested CCCS institutions and departments in order to adapt WeBWorK into the pre-built courses that were previously developed or to develop WeBWorK for other courses in STEM. As the needs and enrollments of each institution can vary greatly, these minigrants

would allow for instructors and departments to develop OER and zero-textbook cost classes that would have the most impact on an individual campus basis.

Lastly, this grant provided for the expansion of CCCS's IT infrastructure to support the project. Colorado Community College System's IT department needed to use and maintain the server space that now would support the WeBWorK homework platform, including the problem creation and course creation, being done at all thirteen member institutions of CCCS. CCCS's IT department plans to host this project in the CCCS data center in the short term, with plans to eventually migrate to Amazon Web Services in order to facilitate future scalability.

Due to the COVID-19 pandemic and the resulting global health emergency, not all the objectives in this grant were completed within the originally projected timeline, though all the goals were eventually met.

Grant #3: Colorado Department of Higher Education Open Educational Resources Grant-- WeBWorK Consortium Part 2: A Collaborative Data Source for Math Instruction (2021-2022)

The third and final grant of WeBWorK implementation across CCCS member institutions had two objectives to support the expansion of the program. Firstly, James Morski and Son Duong (replacing Brenda Forland) created a more advanced version of the WeBWork training. This advanced training would teach interested math faculty across CCCS how to author questions in WeBWorK using the Problem Generation programming language. This training was developed as a five-week remote synchronous course offered during the summer of 2021, and due to high interest, was offered again in the summer of 2022. Increasing the number of CCCS faculty who can program questions and develop coursework using WeBWorK beyond the basics of liaison training allows for more robust development for math and other STEM classes as OER and zero-textbook cost courses.

Secondly, this grant provided 18.5 credits of minigrant funding to Arapahoe Community College's math department to program questions for their highest enrollment math courses. Arapahoe Community College is a CCCS institution with one of the highest student enrollments, and their faculty's interest in the program allowed for special funding from this larger grant. These courses included Math for Liberal Arts (MAT 120), Intro to Statistics (MAT 135), and Linear Algebra (MAT 225). These questions were created and adopted for use in the Fall 2022 semester, after which a committee will review and revise the questions to make the updated and

most usable versions available for others in Colorado to use. This work is currently in progress.

Outside of the grant funding that was received in 2020 cycle, CCCS has made a number of in-kind contributions towards the success of the WeBWorK project. These include more than $3,000 towards the payments of the trainees and the facilitation of the training themselves, both physically and virtually. Brittany Dudek, the CCCS Director of Library and OER services for the system office, has also contributed a significant amount of time and effort to secure the funding for the two Colorado Department of Higher Education grants as well as worked to administrate these grants collaboratively among all stakeholders.

CCCS IT continues to support and sustain the WeBWorK project, allowing for WeBWorK to be used across institutions with minimal disruption. This support takes the form of maintaining the server to allow for all CCCS colleges to use WeBWorK, dedicating 20% FTE to system administration responsibilities, preforming application and server upgrades, and preforming server, network, and backend troubleshooting for all CCCS institutions using WeBWorK.

Results & Shareable Tools

As a result of this work facilitated by the collaboration of instructional faculty and the Colorado Community College System, ten of the thirteen CCCS colleges have trained liaisons for WeBWorK. Having a liaison in place means that math classes using WeBWorK are available and being currently taken by students, or that courses and problem sets using WeBWorK are in development, or they have the institutional capacity to be developed. Currently, ninety-four math courses are using WeBWorK with an estimated cost savings to students throughout the CCCS system of around 2 million dollars. While no student is ever "excited" about textbooks and homework, math instructors using WeBWorK in their courses have expressed student satisfaction with not having to buy a proprietary textbook and homework program. Instructors have also expressed satisfaction with using WeBWorK in their classes, as the flexibility to choose from many pre-articulated problems combined with the ability to author their own makes for more nimble and responsive course design.

The WeBWorK training materials, problem sets, and course shells are all available through CCCS's institutional repository. For more information, email Brittany Dudek

at Brittany.Dudek@cccs.edu. This successful collaborative partnership of the Colorado Community College System office and institutional faculty at institutions within the consortium can also provide a model of how to leverage existing resources in a higher education community to further equity goals using OER. The writing, administration, and implementation of grants does not have to solely fall to those also doing the teaching and instructional design. Allowing other stakeholders to be involved with the grant process ensures that instructional faculty have more time and energy to bring to the project itself and those with administrators with experience with the grant-making process can use their expertise for increased successful outcomes for all.

Lessons Learned

This project took a large amount of communication, collaboration, and work by both the CCCS project staff and the instructional faculty across several different institutions. While the faculty were monetarily compensated through the different grant funding allocations for their time, the bandwidth for all stakeholders to take on extra work on top of instructional and departmental duties remained an issue when completing tasks and objectives. The challenges in this area only increased with the onset of the Covid-19 pandemic and society experiencing a collective trauma while pivoting to teaching completely online. Furthermore, extensive training is required when learning a new technology with a steep learning curve such as WeBWorK. Morski, Forland, and their original team estimated that the first implementation of WeBWorK for College Algebra took over 500 hours of work to code the homework sets for the class. This was much longer than they originally anticipated; training liaisons and developing training effective training materials also presented time-management challenges. The ability for all parties to pivot expectations when these issues arose was a key driver of success for the implementation team.

While collaboration across different institutions and job roles led to the success of the WeBWork project, stakeholders also realize that administrative tasks which cross departments (business/financial, library, and academic) should be included in resource planning at the beginning of the project. Dividing up these responsibilities and articulating the process for doing this work would have made for a smoother implementation process. Finally, new strategic priorities at any participating institution or at the system office level may end up changing departmental or college goals; changing priorities may mean that stakeholders no longer can engage

fully in a cross-institutional project and workloads subsequently may need to change.

Next Steps

Colorado Online @ (a transition to a centralized student services and online teaching model for CCCOnline and CCCS's member colleges) and will fully replace CCCOnline by early 2024. This transition has come with a reshuffling of institutional priorities for both CCCS and its member schools, making the next steps in expanding this project somewhat uncertain. CCCS will continue to host the WeBWorK server to ensure that WeBWorK is available to any courses that use it or would like to use it in the future. As materials for these STEM courses are created or updated, CCCS will continue to host them in the CCCS Learning Repository. CCCS is also in the process of hiring a Learning Resources Coordinator, who will be responsible for managing all course materials (including OER materials) for the Colorado Community College System. Part of this role's job duties will be to make all STEM instructors and faculty aware of WeBWorK as an option for ZTC STEM course materials and put interested parties in contact with those who can provide training on its implementation. Addressing the historically heavy textbook cost for those students interested in perusing STEM as a matter of student equity is an institutional priority for CCCS; learning, training, and using WeBWorK across different STEM disciplines will remain a vital tool for doing this work moving forward.

References

CCCS Facts and Figures. (2023). CCCS. Retrieved March 8, 2023, from

https://cccs.edu/about-cccs/cccs-facts-figures/ .

d'Entremont, A. (2021, November 8). *OER in STEM: Opportunities & challenges*. Open UBC. https://open.ubc.ca/oer-in-stem-opportunities-challenges/

Gans, J. (2019, September 2). Cost of STEM course textbooks can top hundreds of dollars. The GW Hatchet. https://www.gwhatchet.com/2019/09/02/stem-course-materials-about-   85-percent-costlier-than-humanities-arts-textbooks/

Jenkins, J. J., Sánchez, L. A., Schraedley, M. A. K., Hannans, J., Navick, N., & Young, J. (2020).   Textbook broke: Textbook affordability as a social justice issue. *Journal of Interactive   Media in Education*, *2020*(1), 3. 10.5334/jime.549

Martin, M. T., Belikov, O. M., Hilton III, J., Wiley, D., & Fischer, L. (2017). Analysis of student and faculty perceptions of textbook costs in higher education. *Open Praxis*, *9*(1), 79-91.   http://doi.org/10.5944/openpraxis.9.1.432

The Hope Center for College, Community, and Justice at Temple University. (2021). *System   Report for Colorado Community College System*. The Hope Center for College,   Community, and Justice at Temple University.

The WebWorK Project. (n.d.). The WebWorK Project. Retrieved February 15, 2023 from   https://openwebwork.org/the-webwork-project-twp/.