Developmental Math Design for a Science/Math Bridge Program: An Accelerated Approach to Basic Skills Remediation

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ABSTRACT

In Fall 2008 an innovative Bridge program was piloted at Madison Area Technical College (Madison College). This program was developed to increase opportunities for lower skilled individuals to access the college's science based associate degree programs. The Science Math Bridge pairs General Chemistry (credit course) with a non-credit developmental mathematics course and a technical reading course specifically designed to support the chemistry curriculum. General Chemistry is the gatekeeper course for many of the science based occupational programs at the college. Traditionally students must have reached a predetermined cut-off score on an algebra focused math assessment prior to enrolling in General Chemistry. Students not enrolled in the Bridge program often require an extra year of developmental math courses before beginning General Chemistry and may still have difficulty performing the required calculations. The Bridge program accelerates developmental education thereby reducing the remediation time before applying to an occupational program. So far five cohorts of students have gone through the Bridge program with promising results as evidenced by the success rate of students passing General Chemistry with a C or higher and comparison of pre and post math assessment scores. Applied Math for Chemistry (AMC) was developed by faculty in the College Preparedness and Academic Advancement Center (CPAAC) at Madison College. The curriculum was developed by compiling a list of math skills/competencies required for chemistry by a team of math and science instructors. This required the collaboration of math instructors within the developmental department, CPAAC, and the Arts and Sciences faculty who teach the chemistry course. The result of those meetings was a Course Outcome Guide for the AMC course. This tool was then used in the preparation of the AMC course syllabus and instructional schedule. The instructional schedule was developed to ensure that the curriculum was aligned and integrated with the chemistry schedule. The AMC course emphasizes dimensional analysis as a problem solving tool. Besides gaining experience in applying mathematics to chemistry problems, the students review basic math concepts such as fractions, decimals, ratios and proportions, percents, exponents, and scientific notation. Learning to use a scientific calculator appropriately and efficiently is an objective in the course for the students. Specific algebra skills that are covered include operations with signed numbers, solving linear equations in one variable, rearranging formulas, and drawing graphs. There is an emphasis on developing general problem solving skills, mental estimation skills, and checking answers to see if they are reasonable and include the appropriate units. Ten percent of the math grade is incorporated into the General Chemistry grade. Teaching math within the context of chemistry more closely connects the students to their occupational goals and is a highly motivating factor in their success. The students in each cohort form a cohesive learning community who study together outside of class and are very supportive of each other.

Keywords: STEM, Best Practices, Student Retention

BACKGROUND

In 2007 Madison College was awarded a Community Based Job Training Grant (CBJTG) from the U.S. Department of Labor to develop career pathways to prepare students for jobs in the biotechnology and laboratory-based industries. One of the programs piloted as a result of this grant was a Science-Math Bridge (Bridge). The goal of the Bridge was to improve post-secondary transitions for lower-skilled adults into science based occupational programs. The Science-Math Bridge pairs General Chemistry with an applied mathematics course and a technical reading course that were specifically designed to support the chemistry content. Programs such as the Bridge provide a tool for students to progress from developmental (noncredit) instruction to college level instruction; they also accelerate entry into the workforce with the prospect of higher paying, quality jobs. This project required the active cooperation between the academic division of this institution and the developmental division.

General Chemistry was the academic course chosen for this pilot study as it is the gatekeeper course for acceptance into science-based associate degree programs (for example, Veterinary Tech, Clinical Lab Tech, Associate Degree Nursing). Traditionally, students are unable to take General Chemistry unless they have completed a sequence of developmental math courses or have scored a 30+ on the Algebra Compass test. Students participating in the Bridge must have a 30+ PreAlgebra Compass score in order to participate. This cut-off score is significantly lower than that required for the traditional General Chemistry. In order to achieve the desired outcomes, a math curriculum was required that combined a review of basic math concepts and introductory algebra and was contextualized for the paired chemistry course. This curriculum was delivered in one semester simultaneously with the introductory chemistry course, thereby accelerating the remediation time. The Bridge program follows a learning community model in that a cohort of students are enrolled in the math, chemistry, and reading classes at the same time; all the students are working towards a common goal of completing General Chemistry and then applying to the science based occupational program of their choice. The focus of this paper is to describe the design and delivery of the AMC curriculum. Outcomes from the AMC course are also discussed.

COURSE DESIGN

Course Outcome Guide

The first step in the curriculum development process for the AMC course was to develop a Course Outcome Guide. This guide helped to focus the course content and goals. A faculty team composed of both math and chemistry instructors gathered to create a visual map of the skills needed to succeed in General Chemistry (Stiehl & Lewchuk, 2005). This interactive session resulted in a list of skills that were compiled and organized. The principal author reviewed the list of proposed math skills and also studied the course competencies for General Chemistry. Those competencies that required mathematical calculations were noted. In addition to the competencies, there was a list of suggested problems from the chemistry text. If a problem required a calculation, the specific math skills needed to complete the problem was recorded. The chemistry lab manual was also examined. To further assist in the preparation of the math

curriculum the principal author visited and observed most of the chemistry lectures and all of the lab sessions during the summer of 2007. Finally, after compiling the information, a Course Outcome Guide was written that included the following: prerequisites, outcomes, concepts, issues, skills, and assessment tasks.

Instructional Schedule

To construct the math instructional schedule, the math skills were ordered sequentially so that each new skill was built upon a previous skill. At this point the General Chemistry instructional schedule (both lecture and lab) was consulted to determine how the math skills would fit with these schedules. The AMC instructional schedule evolved over the course of four semesters. In the end there needed to be flexibility in designing both the chemistry and math instructional schedules. The lab chemistry schedule was adjusted for the Math/Science Bridge by moving the math "heavy" labs farther back in the instructional schedule to give the math instructors time to prepare the students for the types of calculations they would encounter. In addition, the chemistry instructional lecture schedule was adjusted so that the introduction of the metric system and dimensional analysis came after the math instructors had time to review the following math concepts: number line and signed numbers, order of operations, fractions, place values, decimals, rounding, powers of ten and scientific notation. In general, the math instructors introduced a math concept prior to the students being exposed to it in chemistry class. For example, the Bridge students reviewed percentages before any percent composition by mass calculations were done in the paired chemistry course. There was considerable overlap in instruction between the developmental math instructor and the content instructor; stoichiometric calculations were covered in the paired courses at roughly the same time. After stoichiometry, the chemistry instructor switched to Bonding and Electron Configurations. At this time the math curriculum included an introduction to basic algebraic principles and solving equations. The students applied this knowledge to solving for a variable in a formula and substituting a known value into an equation. When Gas Laws and Behavior were introduced in the chemistry course, the students were ready to use the formulas. Throughout the course, contextualization of the math curriculum began very quickly after the initial math concept was presented. The bridge students encountered all of the chemistry calculations in both the paired math and chemistry courses.

The math course was divided into the following Units of Instruction that were integrated with the chemistry instructional schedule: 1) Introductory Math Activities, 2) Graphing, 3) Decimals and Scientific Notation, 4) Metric System, 5) Significant Figures, 6) Dimensional Analysis, 7) Proportions and Percent, 8) Mole Relationships, 9) Stoichiometry, 10) Algebra, 11) Formulas, 12) Gas Laws, and 13) Molarity/Concentration Expressions. Each of these units had their own lesson plans, warm-ups, in class practice problems, applied word problems, group projects, web resources, homework, and assessments.

Syllabus

After completing a draft of the AMC instructional schedule a syllabus was written to inform the students about the course content, grading schema, and expectations. The four components of the course grade and corresponding percentages were: 1) Exams – 40%, 2) Quizzes – 20%, 3) Group Projects - 20%, and 4) Homework - 20%. None of the four exam grades were dropped, however a student could earn back a maximum of 50% of the points they lost by filling out a Diagnostic

Learning Log (Angelo & Cross, 1993) and correcting their mistakes. Specifically, the students needed to identify the step(s) that led to an incorrect response, redo the problem showing their work, and then state why they believed their answer was now correct. Two of the weekly quiz grades were dropped. There were no make-ups on the quizzes. Group Projects occurred at the end of each unit. These in class activities occurred at least once every two weeks. Students that were absent on a day a group project was assigned could complete the project on their own and earn a maximum of 75% of the original points. Homework was checked for accuracy and completion. Feedback was provided to students if their solutions contained errors, although points were not deducted. Students did not earn college credit for this developmental math course. However, after the first semester of the Bridge program, ten percent of the math grade was incorporated into the paired chemistry course grade to acknowledge the effort and time commitment made by these students.

Textbooks

After previewing a number of math textbooks for chemistry students, the principal author chose to use *Math Review with Algebra* by Peter Esser, Southwest Technical College. It is available for purchase at Lulu Self Publishing Company. The text was customized for the Bridge program by including the following chapters: Fractions, Decimals, Percents, Measurement, Formulas, and Algebra. Each chapter reviews basic concepts and includes numerous practice sets with applied word problems. Students were also assigned math problems from their chemistry text throughout the semester. This was the same textbook used in the paired chemistry course, *Introduction to Chemistry* (Bauer, Birk, Marks) 2nd Edition; ISBN 978-0-07-351107-8. The chemistry and math instructors did not assign the same problems.

COURSE DELIVERY

Class Activities

The developmental math instructors were able to include diverse instructional activities within the classroom because of the extended time allowed. The Bridge math class consisted of three sessions per week. Two of the classes met for 80 minutes and the third for 110 minutes. Each class session began with a Warm-Up that was comprehensive in nature and designed to be finished in 5 - 10 minutes. Time was available in class to discuss any problems that students were currently having with their math calculations. After the instructor modeled the next math skill, the students immediately tried some practice problems. Applied math problems were next introduced. These problems were similar to the ones that the students would see in the chemistry class. Content was layered between math and science. Math was presented as a tool to succeed in science. Because the students' goal was to enter a science based occupational program, applied word problems were also included that recognized their interests in health occupations or veterinary technology, for example. Each class session was composed of individual work time and group activities so that the students would learn how to effectively communicate as a member of a team. Because the classrooms had computer stations for each student, suitable web-based interactive activities were available for practice within the week. A portion of each class session prior to an exam was reserved for reviewing pertinent material; students received a Study Guide one week prior to each exam that was aligned with the skills listed in the Course Outcome Guide. The math instructors gave their exams covering preparatory content prior to the scheduled chemistry exams. In this way the students were able to study their math calculations in advance of the chemistry test; once the math exam was over, they could focus on the pure chemistry

competencies. Finally, a field trip was taken each semester to a local company that employs large numbers of people holding science based certificates or degrees. Here students could observe employees performing a variety of job duties that required both knowledge of math and science.

Group Projects were handed out at the end of each unit. These projects were designed for the students to complete in class in groups of two or three. Each student needed to turn in their own completed handout and these were graded for completeness and accuracy. The projects contained a variety of exercises that reviewed the material for that particular unit. For example, the Formulas Group Project included the following activities: reading and using formulas as tools, rearranging formulas, and applied math word problems.

Problem Solving Approaches

One of our major goals as math instructors was to facilitate the development of a broad problem solving approach in our students. We wanted the students to also be able to estimate an answer and conclude if it was reasonable or not. Most Bridge students came into the program with difficulties recognizing general categories of word problems, the specific question asked in the problem, the pertinent numbers, and the steps required for solving a word problem. They had little, if any experience, designing a road map from start to finish when solving an applied problem. These students were not only inadequately prepared in basic arithmetic skills but often had anxiety related to prior poor performance in a math course. When confronted with a word problem, some math students will first try to solve it by randomly plugging numbers into any equation they think might be useful. To overcome this approach, the students at the beginning of each semester were given a series of Problem Recognition Task activities. These activities involved reading a list of word problems but not solving them. The learners were asked to underline the question being asked, circle any key words designating a mathematical operation, think of additional key words that signaled an operation, and then write a similar type of problem for each of the given examples. Initially these learner-centered activities involved word problems taken from daily life and then selected word problems from the chemistry text. After dimensional analysis was introduced, the students continued to work on word problem organization.

Alone or in pairs, students were asked to read a problem, identify the wanted units (single or ratio), identify the starting units (single or ratio), and to find and list any conversion factors within the problem. Other exercises directed the learners to provide the same information but construct a road map from starting units to wanted units. Eventually, the students were asked to document their problem solutions by organizing the data in table form and providing a written statement outlining their strategy to solve the problem (Angelo & Cross, 1993). The students were also requested to provide a written statement expressing why they thought their answer was reasonable. To facilitate this process, the students were given a Word Problem Self-Assessment checklist, similar to the rubric used by the instructors to grade applied math problems on exams. Creating their own word problems to share with the class was another activity used frequently. Some of these problems appeared on quizzes and exams. Because this was an applied chemistry math course, there was an emphasis on frequently used conversion factors in chemistry calculations such as molar mass, Avogadro's number, mole ratio, density, and molarity. To facilitate the appropriate application of these conversion factors, one of the authors created a visual diagram illustrating the connections between the conversion factors and the units. One homework assignment gave the students five different pairs of wanted and starting units. The

students' task was to write an original word problem using these units. In addition, they specifically needed to identify the conversion factor(s) required to solve the problem. These problems were collected and exchanged with other class members for an in class activity.

Assessment

Continuous assessment of student progress was practiced by the instructors. Besides summative assessments such as exams and group projects, frequent formative assessment was employed in the classroom. A variety of classroom assessment techniques were used to gauge student learning. For example, Daily Warm-Ups provided information as to whether a particular skill needed more practice. Furthermore, the instructors spent time talking to individual students and observing their problem solving skills. At other times students were given index cards at the end of the class period so that students could write down anything that confused them in the session. Findings were shared with the class. This anonymous feedback helped the instructors focus on the needs of the learners and provide continuous improvement. Moreover, students were asked to jot down what they saw as their personal strengths and weaknesses in the context of math. Learner reaction to instruction was assessed informally by handing out index cards and asking the students to provide comments about the course and the Bridge program; this occurred three or four times during the semester. At the end of the semester, the math students filled out an extensive online survey evaluating the course, the instructor, class materials, activities, and the Bridge program in general. Most of the questions required a written response.

Communication and Technology

To facilitate communication between all the Bridge instructors, weekly meetings were held throughout the semester. During these meetings the chemistry, math, and reading instructor discussed the instructional schedules to determine current course alignment. In addition, the meetings were used to coordinate exam dates, flag any potential problems with students, share curriculum, and follow-up on previous issues. Blackboard was used as the Course Management tool. Here students could access their grades and view course documents, assignments, practice problems and keys, quiz keys, study guides, tutorials, web links, and the class journal (weekly summary of class activities and handouts).

RESULTS

TABLE 1: ACADEMIC RESULTS AND OUTCOMES

Math Grade	Chemistry Grade	Math COMPASS Score	Math TABE[1] Score
56/60 passed with C or higher 41/60 passed with an AB or higher	56/60 passed with C or higher	40/44 students who took Compass both pre- and post-Bridge improved their score	53/59 students improved or maintained their score (1 did not post-test)

[1] Test of Adult Basic Education; administered first week of semester and at the end of same semester

Table 1 includes data related to final math and chemistry grades and performance on both the COMPASS placement test and the TABE assessment. Sixty students completed the Bridge program over five semesters in this pilot study. As shown in Table 1, 93% of the students completing the Bridge program chemistry course passed with a C or higher. This compares to 77% of students enrolled in the traditional chemistry course (Center On Wisconsin Strategy [COWS], 2010). Similarly, 93% of the students who completed the Bridge program received a C or higher in the AMC course. In fact, 68% of the students in this pilot study achieved an AB or higher in the math course. Besides those academic results, 91% of those students who took the COMPASS math post- test improved their score. Finally, 90% of the students completing the math course either improved or maintained their scores on the TABE test (COWS, 2010).

DISCUSSION

Prior to developing the curriculum for the Applied Math for Chemistry course the following question was asked, "Does the traditional sequence of developmental math courses actually prepare the learner to do the types of math calculations required in an introductory chemistry course?" Traditionally students are directed into a sequence of developmental math courses that prepare the learner for college level algebra courses and meet transfer course prerequisites. At Madison College there are two developmental math courses offered currently: Math Concepts and Basic Algebra. Students enrolled in either of these two courses receive developmental credit but not institutional credit. The AMC course was offered as an alternative to Basic Algebra in this study. Students succeeding in Basic Algebra would normally proceed to Elementary Algebra with Applications and then to Intermediate Algebra. This sequence serves a certain population of students very well who plan on progressing to college level algebra and have a different set of goals than the Bridge students. However, the content of Basic Algebra does not adequately prepare learners for the mathematics they encounter in General Chemistry. For success in chemistry, a student needs to review and expand upon skills such as fractions, decimals, proportions and percents. They need a firm grounding in the metric system and scientific notation, neither of which are covered in Basic Algebra. In addition, the learner must be able to solve applied word problems in the context of chemistry. Students do need, however, some basic algebra skills to understand and use formulas which are often encountered in chemistry.

By only taking one developmental math course concurrently with the chemistry course, the traditional sequence has been bypassed. This acceleration of remediation saves time, an issue for adult students returning to school with families. Students facing a year of developmental coursework before starting the chemistry they need before applying to a science based occupational program will often give up before even starting the process. Data from this institution indicates students progressing through the traditional developmental pipeline frequently are not retained before entering their intended program, particularly those interested in a 2- year science based program (COWS, 2009). Studies have shown that the faster students progress towards a credential, the more likely they are to complete college (Bowen, Chingoes, & McPherson, 2009). Paired courses bypass prerequisite requirements that may prohibit developmental students from taking college level courses; they can provide integration of the curriculum for more "just in time" remediation tailored to the needs of the students (Edgecombe, 2011).

Students in the Bridge were part of a learning community that was cohort based and included three linked courses. These students spent 12 hours per week together in the classroom, and many chose to study together outside of class. By sharing a common goal, students in a learning community develop a connectedness and rapport that is not seen in traditional classrooms (Karp, 2011). Cohorts are often associated with stronger social relationships and improved retention (Engstrom and Tinto, 2008). This was observed among the Bridge students who were very supportive of each other. Throughout the semester the learners were involved in numerous group activities. During these times we observed cooperation, sharing of ideas and strategies between the students and peer teaching. Furthermore, collaborative learning activities have the added benefit of reducing math anxiety which is commonly present in our population of students (Higbee & Thomas, 1999). In addition, smaller class size may also have contributed to the formation of a cohesive learning community and the ease of planning group activities. Only 16 students could be enrolled in each section of the Bridge math class; this number corresponds to the maximum number of students allowed in each chemistry lab section. Other developmental math classes at this institution may enroll up to 25 students.

Our instruction in the classroom was student centered with a variety of activities being offered; there was the opportunity for pedagogical experimentation. We were able to do this in part because of the extended time available for instruction in this developmental math course. We had 270 minutes of instructional time per week available as compared to 200 minutes in the other developmental math courses. Longer instructional blocks of time are thought to help build stronger social relationships between the instructor and the students and amongst the students themselves. Lower attrition rates and higher course completion rates may be attributed to an instructional approach that is more student centered (Edgecombe, 2011).

Besides accelerating the remediation time by pairing the math and chemistry courses, the AMC course implemented contextualization of the curriculum. The basic skills instruction was customized for the chemistry content. In addition to their Adult Basic Education training, both math instructors have a background and training in the sciences. This expertise facilitated their ability to answer the students' questions and contextualize the curriculum. The students learned primarily math in the course, but the students were always exposed to the subject area material while practicing those basic skills. The students applied the skills they learned in math class immediately in the chemistry course. Providing instruction that is more relevant to the students enhances motivation. Indeed, as Wlodkowski (1988) states, "When adults need and desire what they are learning, they will tend to be highly motivated" (p. 48). Contextualization of developmental math courses was shown to increase the likelihood of successful remediation, accelerated entry into college-level coursework, and success in college-level and transferrable coursework (Wisely, 2009).

Customizing the curriculum requires a considerable effort, but the benefit lies in the improved outcomes for the students such as passing grades and mastery of skills. There has been some concern that instructional approaches such as the one used in this study leads to "over contextualization" whereby the learners can only apply their skills to one content area (Perrin, 2011). The results of this preliminary study suggest this was not the case. Both the TABE and the Compass do not use word problems specifically related to chemistry. Assessments in the course itself covered both basic skills and content area knowledge.

Attrition was low in the AMC class; 20% of the students enrolled initially withdrew from the math course. About half of these students did not attend the first class period. To compare, approximately 50% of Basic Algebra students withdraw during the course of a semester at this institution. Students could not withdraw from one class only in the Bridge. If they decided to withdraw, they needed to do so for the chemistry, math, and reading courses. The Bridge was a "package deal".

CHALLENGES AND RECOMMENDATIONS

This Bridge program began in Fall 2008, and the pilot lasted five semesters before funding ended. Throughout the first three semesters of the Bridge only one section was offered; subsequently during the last two semesters two sections were offered. There were four different chemistry instructors and two math instructors involved in the pilot. The lack of continuity in the chemistry instructors initially led to changes in the math instructional schedule every semester until the last semester when there was final agreement on the joint schedule. Preparing the instructional schedules jointly before the beginning of each semester was a big help. Still, team teaching requires the instructors to be flexible to respond to the students' needs. We found out early on that the chemistry lecture and laboratory schedules needed to be adjusted so that the math instructors would have time to adequately prepare the students for "math heavy" chemistry topics. Once this was adjusted, the math instructors had the time to review the basic skills needed prior to starting the metric system, scientific notation, and dimensional analysis. Furthermore, it was absolutely necessary for the chemistry and math instructors to sit down before the semester began and coordinate assignments from the chemistry text to avoid duplication. During the fifth and last semester of this pilot program, the amount of work involved for the math instructors decreased; the lesson plans and group projects had been revised and teaching the course seemed to be more routine. However, teaching a paired course such as this will probably always involve a greater time commitment because of the need for communication between the teaching faculty and weekly meetings. Nevertheless, we found teaching these math students to be highly rewarding as they were engaged and motivated. One of the comments from the end of the semester math class survey we would like to share is as follows, "I hope that the Bridge course will be offered in the future here at Madison College. It has truly helped me overcome a prerequisite requirement that would have taken much more time and money had I not the option. Now I can continue with my program and complete it in an efficient time frame, and then get back to the workforce. - THANKS MADISON AREA TECHNICAL COLLEGE!!" (Online AMC survey transcript, December 2010).

Because of the initial success of this pilot program, additional funding for a much larger study that involves matched controls is being pursued. The college hopes to be involved in a multi-year evaluation study fully funded by the Office for Planning, Research and Evaluation in the Administration for Children and Families, US Department of Health and Human Services. This study is part of the Innovative Strategies for Increasing Self-Sufficiency (ISIS) project.

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