POINT LOMA NAZARENE UNIVERSITY

Addressing Quantitative Literacy Gaps: Use of an Intervention to meet the needs of Struggling STEM Majors

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by

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Abstract of the Thesis

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by

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In the United States only 40% of students who start a STEM major finish their degree (Olson & Riordan, 2012). One of the obstacles that students face is taking gateway classes such as chemistry. Students are more likely to pass these courses and finish their degree if they have a high level of quantitative literacy (Harris et al., 2020) defined as the ability to use math outside the context of a math classroom (Delgado & Lucero, 2015). The purpose of this study was to examine the effect of an intervention course for college students who were failing their General Chemistry I course. Students were invited to enroll in the eight-week course focused on acquiring quantitative literacy by teaching math skills, problem-solving skills and study skills. The MUST and TOLT assessments (De Pilar Albaladejo et al., 2018, Tobin & Capie, 1984) were used to determine the students' quantitative literacy level pre- and post- intervention. Students had a statistically significant improvement in their math skills, but not in their reasoning skills. When students retook

General Chemistry I the following semester, they were invited to report their scores, and there was a statistically significant increase in both quiz and exam scores. This study supports previous research that instructors need to explicitly teach problem-solving, math skills and study skills along with the science content for students to become successful in gateway courses. Institutions can further support students by creating additional course offerings that will support students' quantitative literacy.

Introduction

Approximately only 40% of college students who start a major in Science, Technology, Engineering, and Math (STEM) finish their degrees (Olson & Riordan 2012). Most students do not complete these majors due to poor performance in required gateway classes such as general chemistry and calculus. In many cases, these low performing students have a high interest in STEM yet, lack essential math skills. This is further compounded when universities do not provide sufficient support for these aspiring STEM majors ultimately pushing them out of the major (Olson & Riordan, 2012).

Students come to colleges from a variety of secondary educational backgrounds. Students who have reflected on their transition from high school to college have noted that after their first year they realized that they lacked the skills necessary to be successful during their freshman chemistry course. Ramos and Towns (2023) reported that undergraduate chemistry students' advice for incoming students was to be ready to study, manage time wisely, and make sure to reach out to resources provided by the college. This shows that students do come to realize some of the deficits that they have in their education, but may not know how to mediate the issue. Additionally, instructors need to be aware that students are entering college with these gaps, and need to not only teach material, but also emphasize the importance of students learning time management, study skills, and asking for help when needed (Ramos & Towns, 2023).

While secondary schools in the United States are required to teach using the Next Generation Science Standards (NGSS), the extent to which students have grasped the material, as well as practiced problem-solving skills such as data analysis, statistical tests, and mathematical routines, unfortunately varies from student to student. These are skills that the College Board (2009) deems that students must be able to use in a science context to be successful in college.

Possession of this skill set is positively correlated with students being able to finish their degrees (Harris et al., 2020). As of right now however, the specific root cause of why some students struggle to place math and science skills together, particularly in chemistry, seems unclear (Hoban et al., 2013).

In math classes, students are taught a variety of basic skills such as solving one variable equations, calculating averages, and graphing. All of these skills should be easily integrated into the science classroom; this is defined as skill transfer (Li et al., 2020). Chinese students who were able to use algebra skills were more likely to succeed in science classes because of this ability to transfer skills to solve novel problems. Attridge and Inglis (2013) noted a similar pattern in which higher level math skills helped college-bound students further develop their reasoning skills, which in turn gives these students a better chance of succeeding in gateway courses as STEM majors. Both of these studies indicated that obtaining a higher level of quantitative literacy (the ability of students to successfully apply math skills outside the math classroom) is essential for students to succeed as STEM majors.

For American students, the SAT and ACT were once markers for students' skill levels in math, which then served as a predictor for student success in science (Donovan & Wheland, 2009). This is because higher math scores in these standardized test showed higher math abilities, which meant that students were most likely to apply knowledge to novel problems. However, it was later determined that these ACT and SAT scores could be keeping students from low socioeconomic status from being admitted into college, and this is one of many reasons why these scores are not currently as prevalent in the college application process (Stitzel & Raje, 2022). Recently, Chetty et al. (2023) called for colleges to bring back SAT and ACT scores as part of the application process. They argue that despite higher socioeconomic status (SES) students being more prepared and having stronger extracurriculars, standardized testing still provides an essential predictor of how students will fare in college despite their SES. Without this data, college admissions staff lack insight into the knowledge level of their incoming class. Some colleges have responded by lowering prerequisite requirements for their students, while others have established their own entrance exams for students who are planning to enroll in chemistry and some rely more on students' high school GPA’s (Johnston et al., 2016; King & Cattlin, 2015). All of these studies indicate that colleges actually serve students better by requiring a measurement of essential student math skills to determine what levels of support they need to succeed as a STEM major. Without assessments and a proper response to students' current levels of math and science knowledge, the trend of students leaving STEM fields is likely to continue.

These issues are further compounded when instructors assume that students can fill any gaps that they have in their math or science knowledge implicitly. Implicit learning is when learners are immersed in a culture in which learning about a certain topic is not the purpose (Reber, 1967). This is commonly seen when culture and the world around the learner helps define certain terms or rules. One of the most prominent examples of this is when children learn their first language and basic grammar. The constant exposure of these skills is so often seen as part of their world that the child learns from these experiences, and is able to apply the rules without intentionally trying to learn them. In a science context, this could be an instructor going over some math as it relates to a science concept, without it being an itemized part of the lecture.

The issue with implicit learning of math skills is that even though it might be ingrained in the culture of practicing scientists, the connection between math and other subjects is not obvious for some students as they are still just learning the culture of science, thus not allowing them to develop quantitative literacy. When instructors assume that students have essential math skills, the new science content is put in the forefront and the related math is glossed over. Delgado and Lucero (2015) collected data about how well undergraduate students could generate a graph. Student samples and interviews were collected from different students representing various majors over six semesters. During the semester, students were shown a variety of graphs and timelines using different scales before going to discussion groups, where they were asked to create their own graphs and timelines at the beginning and end of a semester. These graphs and timelines covered a range of historic events which made arranging the x-axis complex. By the end of the semester, Delgado and Lucero (2015) noticed that there was still a large group of students unable to create these graphs and timelines despite seeing examples throughout the semester. Beck (2018) did a similar study with statistics in an undergraduate biology class. In each organismal biology and ecology course, the biology content was emphasized whereas the statistics, problem solving, and what the results meant were not. When students were then given statistics problems to solve on their own, it was found that there was no gain in their abilities to solve them. This shows that many students do not gain quantitative literacy unless they are explicitly taught math skills in the science classroom.

Colleges admitting students of varied skill levels in math and science are faced with the challenge of creating support systems for aspiring STEM majors. In order to prevent failure in gateway classes, universities and professors must be willing to create classroom and institutional supports that aid the growth of quantitative literacy skills.

Purpose Statement:

The purpose of this study is two-fold. First, to determine the level of quantitative literacy, confidence levels toward using quantitative literacy, math skills, and reasoning skills of undergraduate students who are currently struggling in a general chemistry I course. Second, to determine the effectiveness of an optional 8-week intervention course created so that they can acquire the essential qualitative literacy skills to become successful STEM majors.

Literature Review

Theoretical Framework

The application of mathematics outside the realm of math class is defined as *quantitative literacy* (Delgado & Lucero, 2015). Students that are able to successfully transfer math skills from one class to another have learned problem-solving skills that they can apply to a variety of contexts.

According to Vygotsky (1978), early math and science learners can be influenced by watching, imitating and asking questions. The classroom provides a learning environment in which students can learn from their peers or a knowledgeable other. Teachers in the science classroom therefore have the task of modeling the integration of math and science as well as of creating learning experiences in which students can practice these skills. Further, Vygotsky noted that learning new skills is best accomplished in the zone of proximal development (ZPD). This zone is an area in which the task is not so easy that the learner does not learn, but also that the task is not too hard causing the learner to give up. In groups, learners are able to achieve within their ZPD, first with help of their group, and later on they can accomplish a task individually. In order to accomplish this in the science classroom, teachers must create lessons that use both science and math skills as well as assessing students' current skill level. In doing so, students can be placed in an environment in which they are challenged by working on more complex problems in groups with teacher support as needed so that later they can work on these problems individually. By going through this learning process, students are able to increase their quantitative literacy skills.

Brown et al. (1989) developed an additional perspective on learning to develop quantitative literacy called situated cognition. In situated cognition, students acquire the cultural norms of the science discipline by working in an authentic context. This would mean developing an environment that has students using concrete and real-life examples in front of them to engage in relevant and grounded problem-solving the same way scientists and engineers do. In doing so, students are not only learning about math, they also participate in authentically-designed environments where they learn where, when, and how to use the practices and skills that they have learned.

When it comes to the science classroom, students are often not able to transfer the math skills that they have learned into a new context because they have lacked exposure to solving authentic problems. Without this authentic practice in both science and math classrooms, students miss the opportunity to increase their quantitative literacy skills and improve their understanding of math and science.

While teaching the culture of a discipline, teachers must guide students into what Ericsson et al. (1993) described as deliberate practice. Deliberate practice is when a learner is guided on how to perform certain tasks and over time is challenged with more novel problems. With deliberate practice, students in the science classroom become focused on improving their skills as a scientist in the science classroom, while teachers act more as coaches giving consistent feedback and challenging them with more complex problem-solving tasks. It is important for science teachers to not just focus on concepts of the discipline, but rather on the underlying concepts and how they are proven experimentally. This often requires students to know how to read, analyze, calculate, and decipher data. Students without these math skills lack the deliberate practice that they need to grow in the field of science. In contrast, students who have experienced deliberate practice already know how to use math skills in the science context, therefore they are more likely to be able to learn how to apply math in future courses. Without enough practice integrating math and science, students are not able to develop quantitative literacy (Ericsson et al., 1993).

The Growing Mathematics and Science Achievements Gap in U.S. Students

The disparity in math skills that can lead to poor quantitative literacy in students from the United States can be seen early in education. The Trends in International Mathematics and Science Study (TIMSS) is used every four years to assess the math and science skills of 4th and 8th grade students. For both groups, students in the United States have above average scores as compared to other countries, yet there are large score gaps in both math and science. High performing students and low performing students had a 24-point gap in both math and science assessments, the second largest performance gap in the countries that were tested (TIMSS, 2021). These testing results show that achievement gaps for math and science skills happen as early as 4th grade and continue to widen into 8th grade, which contribute to lower quantitative literacy skills when these students enter college. Another international test at the high school level, Programme for International Student Assessment (PISA), assesses 15-year-olds on a variety of topics including reading, math, and science. In 2022, math students from the United States scored 66% on average, which was below the Organisation for Economic Co-operation and Development (OECD) average of 69% for all countries tested (OECD, 2023). At this level, U.S. students were able to recognize and complete simple math problems but failed to complete more complex problems (OECD, 2023). When looking at overall trends from 2012 to 2022, the OECD notes the U.S. math performance overall has declined, showing that even if teachers have a specific teaching credential, as seen in U.S. middle and high schools, achievement gaps continue to widen. These results were then confirmed at the community college level by Cohen and Kelly (2019), in which the level of math courses successfully completed by a student determines the probability of staying a STEM major. This indicates that supporting the development of math skills throughout a student's education is essential for success in the STEM field and that students who do not have these supports are at risk of failing to succeed as STEM majors due to their lack of skills.

In the chemistry classroom, students need to have ample math skills in order to be successful. Research has explored the reasons behind why many students are unsuccessful in applying their math skills within the science context. Preininger (2016) used a pretest to show that many students entering high school chemistry lack the algebra skills that are needed to do well in the class. It was found that poor math skills could be one of the reasons that students do not have the quantitative literacy skills they need to succeed as a STEM major.

Another reason that students may not be successful in science classes with applied mathematics is that students might have a poor understanding of the science concepts, which creates uncertainty on how the math should be applied. Beck (2018) noted that undergraduate students could not apply math to a science concept that was poorly understood. In this study, Beck tracked the scores of college freshmen in biology courses and found that some students struggle with knowing how to apply math in science classes despite being proficient in statistics. Even if students were able to do well in math, the lack of science skills may prevent them from applying math in a science context.

Negative attitudes which lead to low confidence levels toward math are another reason for low quantitative literacy skills. Students who struggle in math and then see a similar concept in science develop low confidence toward both topics and undervalue math as part of science, stating that it would take too much effort for them to learn proficiently (Andrew & Aikens, 2018; Richland et al., 2012). This is then translated into lower course grades in both science and math for high school and middle school students who view math negatively (Bosco et al., 2022; Judson & Sawanda,2010). Blackwell et al. (2017) noted that low confidence levels caused a negative belief toward how well students can perform in mathematics. Lastly, Fredricks et al. (2017) showed that there was a positive correlation between high school and middle school girls' low confidence toward math and showing low interest in STEM career goals. Knowing that low confidence levels can affect quantitative literacy and achievement in science courses, it is important for instructors to support students as they work on math problems within the science context, especially if they have a low confidence level toward applying math in the science classroom.

Lastly, students may be struggling with problem-solving skills which contribute to poor quantitative literacy. Li et al. (2020) focused on set-shifting, which is the ability to transfer skills from one area to another which will be defined here as problem-solving skills. Students who did not have problem-solving skills were also lacking math skills and therefore, struggling in science as well. Bain et al. (2018) noticed a similar pattern in comparing successful and unsuccessful undergraduate chemistry and physics students. Students who lacked problem-solving skills were not able to link a science concept with the correct equation needed to solve a problem. In order to support students, quantitative literacy instructors must also support problem-solving skills.

Interventions to Support STEM Students

In order to support students in overcoming the issues described above, there have been a variety of interventions described by previous researchers. One broad category is institutional-level interventions to increase quantitative literacy (Table 1), while another broad category is classroom-level interventions (Table 2). The interventions themselves can be further broken down into three major categories: interventions focused on developing students’ math skills and/or science content, interventions focused on developing students problem-solving skills, and interventions focused on improving students' confidence levels towards math and science. These types of interventions are explored further in the following subsections.

Table 1

Summary of Institutional Interventions to Increase Quantitative Literacy

Authors	Sample Size (n)	Intervention Category	Type of intervention	Results
Peursem et al. (2012)	n= 88 Algebra n=37 Quant lit Undergraduate Math	Math	Created quantitative literacy class to teach math application	Students in quantitative literacy course outperformed regular algebra students in increased ability to apply knowledge and transfer knowledge
Benoun (2020)	n=130 Undergraduate Biology/Math	Math and Science	Transformation of calculus classes to be specific for biology majors	Students showed improvement in calculus class as well as application to biology
Shah et al. (2020)	n= 3808 Support Class n= 12694 no support Undergraduate Chemistry	Math, Science and Problem Solving	Students with lower math skills placed in separate smaller lecture with a co-requisite support class. In semester 2, they joined regular class	Students in the smaller class were able to close achievement gaps by focusing on student needs such as problem solving, though in the following semester the achievement gap opened again
Mason & Verdel (2001)	n=17 Large class n=19 Small class Undergraduate Chemistry	Math, Science and Problem Solving	At-risk students were separated into two groups. One group was put into the normal lecture class while another group was placed in a class with other at risk students	Students in the at-risk class were able to outperform students in the larger class due to the smaller class being more adapted to the students' needs
Leonard (2020)	n=21 Bridge program n=23 Control Undergraduate OChem	Math, Science and Problem Solving	Students were placed in a bridge program between Organic Chem I and II	Students in the intervention class were able to show improvement during OChem II
Steele & Kilic-Bahi (2010)	Freshmen n=782 Seniors n=138 Undergraduate	Quantitative Literacy	Students were taught quantitative literacy throughout different college classes as a college-wide initiative	There were some gains between freshmen and senior year.

Institutional-level interventions

The course offerings at the university level are a way colleges can support the increase of quantitative literacy of their students. Some universities have decided to modify math classes with the goal of making students more quantitatively literate. Peursum et al. (2012) compared math scores of students in a traditional math class versus another class that was specifically geared toward quantitative literacy and found that students in the quantitative literacy class were able to apply their knowledge to novel problems better than students in the traditional math class. Benoun (2020) reported a similar finding in a calculus class that was specifically reorganized for biology majors. Students who completed this class gained better knowledge of biology as well as an understanding of how calculus can be applied to the study.

Other universities focused on chemistry in a variety of different ways such as creating bridge courses, co-requisite math skill courses, and/or smaller class sizes. Carlson (2018) and Leonard (2020) used bridge courses as a way to support students. In these bridge courses, students were given the opportunity to practice problem-solving skills as well as to review science material. As a result of this, Leonard (2020) was able to see an improvement in scores during the following semester of organic chemistry. Instead of a separate bridge course, Shah et al (2020) required students with low math scores to enroll in a corequisite in addition to a smaller chemistry class. Based on their chemistry course grades, the corequisite math and science course helped students close achievement gaps according. Similarly, Mason and Verdel (2001) placed at-risk students in a smaller chemistry course and also saw an increase in test scores. Both Shah et al (2020) and Mason & Verdel (2001) credit the success of students to these smaller class sizes that allowed them focus on problem solving and achievement gaps, which can help students improve their quantitative literacy.

Steele and Kilic-Bahi (2010) attempted to mediate the lack of quantitative literacy of college students in which all faculty members were required to integrate quantitative literacy components into their content matter. In order to measure students' progress during this initiative, incoming students’ quantitative literacy skills were assessed, then assessed again prior to graduation as seniors. Though quantitative literacy scores remained at 55% or lower, seniors did show an average increase of 13 percentage points from their scores as freshmen. This shows that despite not seeing the large gains, this intervention did prove useful for increasing students’ quantitative literacy. However, these gains were only possible if the responsibility for making sure that students were practicing quantitative literacy was shared with all faculty members.

Table 2

Summary of Classroom-based Interventions to Increase Quantitative Literacy in the Classroom

Authors	Sample Size (n)	Intervention Category	Type of intervention	Results
Hoban et al. (2013)	n=23 Undergraduate Chemistry	Math	Students completed 2 non-optional math modules	Math skills positively correlated with problem solving ability Reasoning skills lacking
Groen et al. (2015)	n=2358 Undergraduate Chemistry	Math	Students completed mastery learning online math support program	Positive outcomes prevent failure in chemistry courses
Johnston et al (2016)	n=153 Undergraduate Chemistry	Math	Students were given the option of using math website as a support during a chemistry class	Students that logged in more often to the math support website were more likely to pass chemistry
Preininger (2016)	n=83 chemistry n=25 elective High School 10-11th	Math and Science	Students were explicitly taught how math is related to science	Students in the chemistry classroom felt more confident doing math and an increase in achievement
Roseno et al. (2015)	n= 288 Control n=165 4th grade	Math and Science	Students were taught FoodMaster curriculum which combined math and science using food	Students that went through the curriculum were better able to solve math problems in a science context and improvement of math knowledge
Judson & Swanda (2000)	n=26 control n=27 experimental 8th grade	Math and Science	Students were taught statistics lessons in both science and math classes concurrently	Students had gain in math assessment scores in statistics no significant gains in science assessments
Alivo et al. (2015)	n=500 Undergraduate Chemistry	Math and/or science	Students completed online review: one class math review or one class chem review both review modules were available to both classes	Math review helped close gaps but may not be specific to intervention because both groups had access to each intervention
Demirdöğen & Lewis (2023)	n=1999 Undergraduate Chemistry	Confidence	Students were taught growth mindset, time management and study skills in class curriculum	Positive impact on student success in assessments
Blackwell et al. (2017)	n=48 n= 43 control 7th grade	Confidence	Students were taught a series of lessons on how intelligence is malleable	Students that went through the intervention had an increase in grades compared to the downward trajectory of the control group
Sansom et al. (2019)	n=421 Undergraduate Chemistry	Problem Solving	Compared 2 years of data one year for comparison the other to teaching conditional knowledge to students explicitly in class	Statistically significant improvement on exams

Classroom-level Interventions to Address Math and Science Content Concerns

Educators have attempted to offer various levels of support at the classroom level to support students developing their quantitative literacy as summarized in Table 2. One such classroom intervention is to support students using math in a science context. Hoben et al. (2013) included four non-optional modules to support undergraduate chemistry students. The first three modules were math-only modules designed for students to practice relevant math skills, while the last module contained math related to thermodynamics in a chemistry context. The goal of these modules was for students to review essential math skills that would be applied later on in the course. As a result, there was a growth in math scores among the students, though their ability to apply math to a chemistry problem was not significantly different from students that did not complete the modules in previous years. Alivo et al. (2020) attempted a similar study with undergraduate chemistry students focused on two different course sections with additional modules. In Course A, students were told to focus on the math review module. In another undergraduate chemistry class taught by the same professor (Course B), students were told to focus on reviewing high school science topics using a separate module. All students enrolled in either course had access to both modules. Alvilo et al. (2020) did see an increase in overall scores in both classes, yet success could not be narrowed down to one module because of open module access. In both Hoben et al. (2013) and Alivo et al. (2020) studies, the completion of math modules by the students did increase scores, yet some students still struggled with the transfer of skills from math to a science context. A longitudinal study was done by Groen et al. (2015) with Australian students in which students enrolled as science majors were given an optional math review over six semesters. Students who completed these online math reviews at any time during the semester were less likely to fail their chemistry classes. Very similarly, Johnston et al. (2016) students were given the option of using a math website as review. Even though most students logged in before exams, the students with more hits on the math support site increased the likelihood of success in chemistry. This shows that instructors adding even an online math review complemented with other teaching methods can help increase students' quantitative literacy which can help them succeed in gateway courses such as chemistry.

Having quantitative literacy integrated into the curriculum has been proven useful at the middle school and elementary school level as well. For example, Roseno et al. (2015) saw that elementary school students who went through the FoodMASTER curriculum which integrates math and science lessons in the context of food science had improvement in their quantitative literacy skills. Students who completed the FoodMASTER program were more likely to solve math problems that were placed in a science context. Judson and Swanda (2000) at the middle school level had math and science teachers collaborate to create statistical lessons in both the math and science classroom. These students were able to find the connections between both topics and had shown improvements in their problem-solving ability as well as increased scores in the statistics unit of their math class. Preininger (2016) used a slightly different approach with high school students. Preininger emphasized how to perform math skills using dimensional analysis as a tool for solving chemistry problems. In addition to this she was able to show students how these math skills can be integrated with the content that they were learning. This explicit teaching consisted of instructors taking time to make sure students knew the math procedures as well as how to apply them to a science context. This allowed students to improve chemistry scores as well as gain confidence in solving problems involving math. All of these studies show that when teachers that make explicit connections between math and science not only increased student achievement in their subject matter, but also have the opportunity to increase students' quantitative literacy skills.

Classroom Interventions to Address Problem Solving Skills

Other classroom interventions have focused on improving the problem-solving skills used to solve complex problems that are essential for STEM majors as described in Table 2. Gayon (2007) identified reasons for why high school students from the Philippines struggle with chemistry and concluded that one of the most compelling reasons for students struggling was not only understanding math and science concepts, but also lacking the process of discerning which specific problem-solving strategies to apply. This sentiment was echoed by students in a survey by Adkins and Noyes (2017) in which students felt that high school math did not transfer into skills that are needed for biology and chemistry, and lacked a full understanding of how math and science are integrated. This shows that students need to have more practice and exposure to more complex science problems that require both math and science skills and not just concept learning.

In the United States Bain et al. (2018) noticed a pattern through student interviews in which students who are successful in chemistry and physics had specific problem-solving strategies which were defined as blended processing. These students were able to first solve the math problem using a specific equation and then create an answer statement using science concepts. On the other hand, students who were not successful in the physical sciences seemed to rely on previous examples of the problem that were often not applied correctly. This shows that students who have higher quantitative literacy skills have a problem-solving process that they are able to rely on when presented with novel problems, but students who lack processing skills also lack quantitative literacy. In an effort to help students develop their quantitative literacy, Leonard (2020) taught problem-solving skills explicitly in a bridge course between Organic Chemistry I

& II. Students who participated in the bridge class were able to show improvement in Organic Chemistry II partially due to practicing problem-solving in the intervention course using a combination of worksheets and think, pair, share activities to review skills from the previous semester. Sansom et al. (2019) explicitly taught problem-solving skills to undergraduate chemistry students using decision charts as a way to exemplify conditional knowledge. Conditional knowledge is a problem-solving strategy for students as it helps them decipher when and why a certain skill is used. Practicing these skills in the classroom ultimately leads to higher test scores for students as they are practicing the thought process of problem solving. Teachers who are willing to teach problem-solving skills and students who practice them are given the tools that they need to become more successful STEM majors. Similarly, Schwartz et al. (2024) gave undergraduate chemistry students a problem-solving template. During discussions and in class, students were shown how to use the template and given the opportunity to practice their problem-solving skills. It was found that when students practiced using the template and teachers scaffolded the exam based on the questions in the template, there was an increase in examination scores. This shows that students who do not have processing skills are able to learn them if they are given scaffolds that can teach them the thought processes needed to solve novel problems, which also give students the ability to increase their own quantitative literacy over time.

Classroom Interventions to Address Low Confidence Levels

The final type of intervention listed in Table 1 is related to student confidence levels. Students having a growth mindset can be a key to increasing quantitative literacy. Growth mindset is the belief that students can obtain skills even if they might not be able to perform a skill at the moment. Blackwell et al. (2007) followed middle school students in math classes with growth mindset lessons embedded in the curriculum. They found that students who were taught growth mindset lessons were more likely to have higher math scores by the end of middle school. Blackwell et al. (2007) also noted that a positive outlook, as well as a growth mindset, helped middle school students enjoy more challenging problems. Knowing a student's mindset and providing the correct amount of support can help them have the correct mentality towards problem-solving, and increase their quantitative literacy. Demirdögen and Lewis (2022) did a similar study with undergraduate chemistry students. In this case, they taught students about growth mindset, time management, and study skills. Using a student survey, researchers found there was an increase in student exam scores when students reported having characteristics related to a growth mindset. These studies provide evidence to support the idea that teaching students about a growth mindset can help students increase their quantitative literacy skills due to their perseverance through more difficult problems.

Instructors can also cultivate confidence toward more difficult problems in students by creating a classroom environment that acknowledges all aspects of student growth. One method of doing this is allowing students to work together on challenging problems as a method of scaffolding their growth in which students work in their zone of proximal development (ZPD) as mentioned earlier. Through student interviews, Fredricks et al. (2017) learned that students felt that they were able to achieve more success when they were working in groups. Johnston et al. (2016) also noted that the growth mindset of undergraduate chemistry students increases if the classroom environment is created where mistakes are taken as learning experiences for students; this can help ease anxiety towards approaching more difficult problems. Lastly, instructors need to make it clear that they believe that students can perform well on challenging problems. Wheeler and Gonezi (2022) note that the instructor's belief in students to succeed in difficult tasks can ultimately empower students and lead to their success. All of these studies show that instructors in gateway classes must continue to create positive classroom environments in which teachers can continue to challenge students in problem-solving skills during class, both individually and in small groups, which can ultimately contribute to increasing their quantitative literacy.

The present study adds to previous studies by combining elements that are known to work individually (e.g., explicitly teaching mathematics skills, teaching problem-solving strategies, and teaching study skills) in a new intervention course designed to help students be successful in their chemistry courses. This intervention exemplifies what can be accomplished when an institution creates a course to meet the needs of struggling students.

Research Questions

The purpose of this study was twofold. First, the study assessed the level of quantitative literacy, problem-solving abilities, and confidence levels toward math used in the science classroom of students who were struggling in their first semester of college chemistry. Secondly, the study assessed the effectiveness of an 8-week intervention course that provided students with fundamental problem-solving and study skills needed for success in the general chemistry sequence taken by STEM majors. To achieve these purposes, the following research questions framed the study:

1. What is the level of quantitative literacy and reasoning levels both before and after an intervention for STEM majors who have not been successful in the first half of a general chemistry course?
2. What are the students' confidence levels toward using math skills in a science context both before and after the intervention?

3. What is the effectiveness of teaching students about quantitative literacy, reasoning skills, and study skills on student achievement during the intervention course as well as when retaking chemistry?

Methodology

Research Design

As shown in Figure 1, this study used a mixed-method sequential exploratory design in order to collect data on quantitative literacy levels and students' confidence levels toward solving math problems within a science context. The qualitative data was used to explain the quantitative data results.

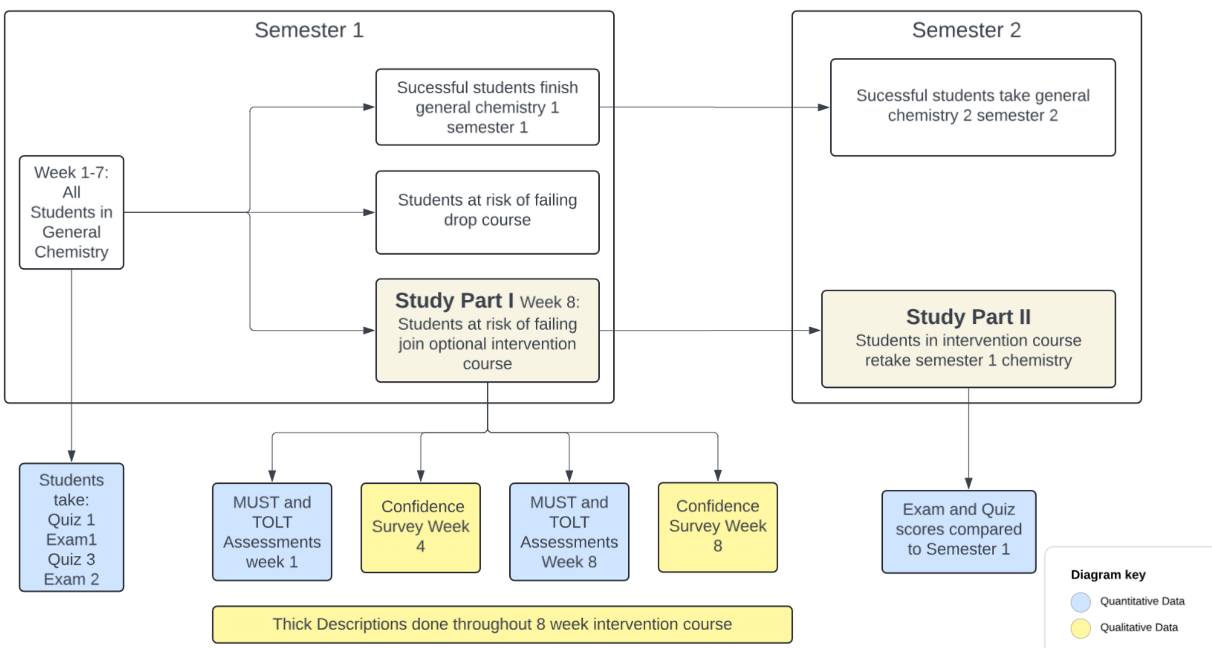
The study took place in two parts: Part I of the study took place during semester one while Part II of the study compared exam and quiz scores in the first half of the chemistry course with those earned after the intervention as the students repeated the chemistry course.

Part I: During the first half of semester one, students who were not passing general chemistry were advised by their professors to drop the chemistry course, and to enroll in the intervention course. During the intervention course, both quantitative and qualitative data was collected. Quantitative data was collected both at the beginning (during week one) and at the end (week eight) in order to measure quantitative literacy levels before and after the interventions. Two assessments were chosen in order to accomplish this. The Math- Up Skills Test (MUST), as shown in Appendix A (De Pilar Albaladejo et al., 2018) and the Test of Logical Thinking (TOLT) as shown in Appendix B (Tobin & Capie, 1984). Qualitative data was also collected during the intervention course in two ways. First, students were asked to fill out an author-developed survey (Appendix C) at the end of each unit in order for them to reflect upon their confidence level toward math and chemistry, as well as their feedback on the intervention course structure. Second, a thick description, as described by Geertz (1973), was written by the author to describe details observed during class related to each students' attendance, participation, engagement, work habits, successes, struggles and confidence toward learning activities.

Part II: During the spring semester, additional quantitative data was collected on students who completed the intervention course and then re-enrolled in the first semester of general chemistry. During the retake semester, scores on all individual quizzes and exams were compared to those earned in the previous semester.

Figure 1

Timeline of Study



Research Site and Participants

The study was conducted at a small, Christian teaching university in southern California in which 65.7% of undergraduate students are female and 34.3% are male. In the university 56.7% of the students are white, 22.4% identify as Hispanic, while 6.5% are Asian American , 8.8% are two or more races, 1.4% are African American, 0.3% Native American, and 0.2% are

Pacific Islander (Goodman, 2023). Students with a score below 50% in their undergraduate general chemistry class at the midpoint of the fall semester were given the option of adding a two-unit intervention course and dropping the four-unit course that they were currently at risk of failing in order to maintain full-time student status. Out of 35 struggling students, 21 chose to participate in the intervention class. After the intervention course, 17 students decided to retake the course during the spring semester, while four students decided to change to a major that would not require them to retake chemistry. Students in both Part I (21 students) and Part II (17 students) were given the option of allowing their work and scores to be part of the study. All aspects of this study were conducted in accordance with Point Loma Nazarene University's Institutional Review Board's guidelines.

Quantitative Data Collection

In Part I, students completed Quiz 1, Exam 1, Quiz 2 and Exam 2 as part of class activities before they were recruited to participate in the intervention. Once in the intervention course, students completed both the MUST and TOLT assessments as a worksheet during the first week of the intervention class to establish a baseline measurement. The MUST is an algebra-focused assessment which De Pilar Albaladejo et al. (2018) used to find that a higher score on this assessment was linked to passing grades in general chemistry. The second assessment, the TOLT was shown by Alvio et al. (2018) and Nicoll and Francisco (2001) to be an effective tool to determine the math and science abilities of students which ultimately helped predict success in chemistry courses.

Students were allotted 20 minutes on separate days to take these assessments during the first week of class meetings for the intervention course. During the middle of the intervention course, students were tasked with completing a Likert-based reflection on the strategies that were taught during the unit and an opportunity to explain why they rated themselves in that manner. At the conclusion of the intervention, students completed the MUST and TOLT assessments for a second time in order to document any changes that were made during the course. During the second semester (Part II), students had the same professor as the intervention course and were invited to report their spring semester scores to measure the effectiveness of the intervention since spring quizzes and exams were equivalent to the fall quizzes and exams. A summary of the course layout can be found in Figure 1.

This course was taught by a chemistry professor in person with the goals of teaching students what was needed to be successful. Most of the course was spent teaching students how to first use conversions, then apply conversions to chemistry, how to problem-solve, how to rearrange equations, and how to study. The intervention course met twice a week for 80 minutes. On Tuesdays the instructor went over how to solve problems and had students try a few of the problem-solving steps that were taught in the course. On Thursdays, students had time to do in-class practice problem worksheets on their own and in small groups with peers, instructors or tutors. During Thursday lessons, instructors and tutors were available to answer student questions. In addition to chemistry instruction, students were also taught lessons about how to study, how to best utilize office hours, review math skills, and time management skills. During the course, students had practice problems on Mastering Chemistry and were tasked with developing their own reading guides for homework (Pearson, 2024).

Qualitative Data Collection

In the confidence survey given to students on Weeks 1 and 8 of the intervention course, students were given the opportunity to self-assess their skill level and confidence level toward the topics that were presented in class. Students were also given an opportunity to reflect on what they needed to become successful, as well as which activities were the most helpful for them. Students were given some examples of the activities done during class, and then asked to describe how those activities were helpful, if they were. In addition, thick descriptions were written by the author during the intervention class meetings. These descriptions included what students did in class that day, student engagement, student questions, as well as overall participation by different groups of students.

Quantitative Data Analysis

During Part I, data from the MUST and TOLT week one and week eight assessment scores were compared using paired t-tests to determine if any changes were made over the course of the intervention. Additionally, Likert scale data from the attitude survey was summarized by calculating average values for each question. In Part II, paired t-tests were done to compare assessment scores from semester 1 and semester 2; for example, both Exam 1 scores were compared, etc. At the end of each intervention unit, students were given a chance to do a self-reflection using a Likert-scale survey on Canvas (LMS system).

Qualitative Data Analysis

Free-response data on the confidence survey was analyzed in order to identify patterns of the student needs, confidence levels, and supports that were identified as the most effective for students. In addition, thick descriptions detailing students' actions and sentiments as seen during class were coded to identify themes and to explain results obtained using the MUST, TOLT and the quantitative portion of the confidence survey.

Results

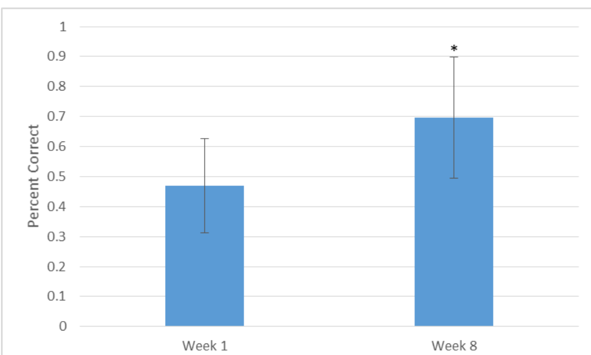
Quantitative Results

The results from the TOLT as shown in Figure 2b compares week one and week eight scores. A summary of all statistics can be found in Table 3. There was no statistically significant difference between the logical thinking of students before and after the intervention. In contrast, the MUST assessments shown in Figure 2a had a statistically significant improvement between week 1 and week 8. The number of students who completed the MUST and the TOLT was different than the total enrollment of the course due to some students' poor attendance as well as adding or dropping the course after the initial assessment was given.

Figure 2

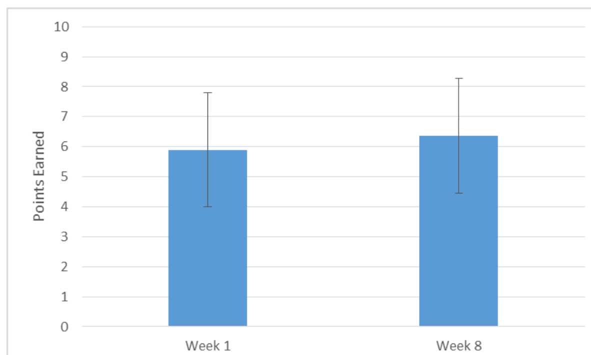
Pre and Post Intervention MUST and TOLT scores

Figure 2a Pre and Post Intervention MUST scores



* indicates statistically significant improvement

Figure 2b Pre and Post Intervention TOLT scores



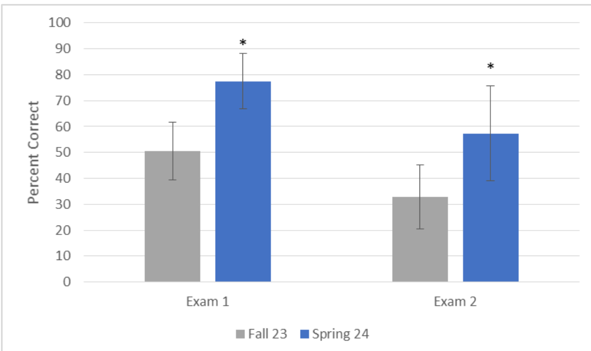
During Part II of the study, exam and quiz scores for the two semesters were compared. All of the assessments were individual student scores. Quiz 2 was not included in the data analysis as this assessment was a group quiz. The differences in average exam scores of students who participated in the intervention class are shown in Figure 3A, while students' average quiz scores are shown in Figure 3B.

During the spring semester students that were part of the intervention course had a statistically significant improvement in all quiz and exam scores compared to the beginning of the fall semester.

Figure 3

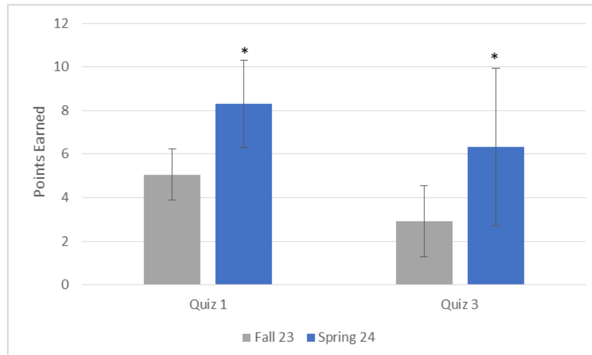
Fall semester and Spring Semester Exam and Quiz Scores

Figure 3A: Comparison of Fall and Spring Exam Scores



* indicates statistically significant improvement

Figure 3B: Comparison of Fall and Spring Quiz Scores



An overall summary of the quantitative assessment result comparisons is shown in Table 3. The median is provided to offer context for the average scores as some students who approach the middle of the semester and know that they are failing traditionally do not try on an exam or do not come to class on exam day, but these students' scores only slightly decreased the mean scores. These results show that after the intervention, student scores showed statistically significant improvements in General Chemistry I as well as improved math skills after the intervention course.

Table 3

Assessment Comparisons

Assessment	Time frame	(n)	Possible score	Mean ±Std Dev	Median	t value	p value
MUST	Week 1	13	100	46.92 ±15.61	45	2.17	0.001*
	Week 8			69.71 ±20.22	75		
TOLT	Week 1	15	10	5.9 ±1.91	6	1.76	0.16
	Week 8			6.36 ±1.91	6		
Quiz 1	Fall	16	10	5.06 ±1.18	5	2.13	5.63E-05 *
	Spring			8.31±1.99	8.75		
Exam 1	Fall	17	100	50.64 ±11.11	50.5	2.12	3.1E-07 *
	Spring			77.44 ±10.70	76		
Quiz 3	Fall	17	10	2.94 ±1.62	3	2.12	0.000117 *
	Spring			6.32 ±3.59	7.5		
Exam 2	Fall	17	100	32.79 ±12.41	34	2.12	1.26E-05 *
	Spring			57.38 ±18.35	60		

* indicates statistically significant improvement

Results from the survey showed there was a greater improvement in confidence levels compared to problem solving abilities and their knowledge of chemistry. Students reported that after the intervention their knowledge of chemistry was a 3.3 while their problem-solving ability was 3.6 on the Likert scale, while their confidence levels rose from a 2.6 before the intervention to a 3.4 at the end of the intervention course.

Qualitative Results

Based on student survey responses, students credited their improvements in chemistry to “learning about study habits”, “memorizing essential atoms and facts” and “learning problem-solving”. According to the open-ended comments in the survey, students emphasized that in the past, they did not find the need to study for exams when learning high school chemistry, while others mentioned that they could not solve problems that were like the example problems, expressing a lack of problem-solving skills. Students also disclosed that they gained confidence toward chemistry problem-solving due to having enough “practice from worksheets” and “group problem-solving” that helped them refine their math and science skills. A summary of student data can be seen on Table 4.

Table 4

Survey Results Categorized by Topic

Fall Semester Struggles	Number of students	Helpful Activities to Improve Understanding of Chemistry	Number of students	Helpful Activities to Improve Confidence Levels	Number of students
Lack of Problem-Solving Skills	7	Teacher Explanations	9	Homework/Individual Practice	10
Memorization	5	Study Skills	8	Small Group Feedback	9
Lack of Study Skills	4	Small Group Work	6	In-Class Practice Problems	3
Lack of Science Knowledge	3	Homework	6	Teaching Others	2
Poor Time Management	1	Class worksheets	4	Exams	2
Asking Questions	1	Tutors	2	Asking Questions	2
		Problem-Solving Skills	2		

Lessons Learned During Intervention	Number of students	Helpful Activities to Increase Problem-Solving Skills	Number of students
How to Study	7	Teacher Explanations	11
Concept Mastery	4	Homework	9
Problem-Solving skills	3	Small Groups	6
Perseverance	2	Study Tips	3
Note Taking	2	Office hours	2
Increase Participation	1		
Go to Office Hours/ Tutoring	1		

Students who participated in the intervention course were divided into three categories based on their performance during the pass/fail intervention course. Five students had excellent participation during the intervention course, eight students had good participation, and four students had poor participation during the course. Using thick descriptions, survey data, and exam scores a profile of a typical student for each student group was created.

Poor participation in the intervention was characterized by students who had low attendance during the eight-week course. Typically, these students attended class about half the time and did not participate well during class such as taking few or no notes, rarely attempting a problem on their own, and asking few or no questions. There was also low effort in activities outside of class such as homework and office hours. For example, a typical student in this group (Student A) did not complete both MUST exams and only improved by one point on the TOLT exam. During the spring semester while retaking the course, this student did show an improvement on quizzes (two points) and exam scores (improved by 30%). Student A credited group work, step-by-step examples and hands-on learning as the teaching strategies that helped them the most, along with learning how to study, take notes, and learning tips on how to handle a heavy load of college coursework.

Students who had good participation during the intervention course came to class most of the time, but not always interacting with classwork or group work. These students tended to be better note takers and at times would answer questions that the professor would ask during class. They usually completed outside of class assignments, but did not typically attend office hours or tutoring. For example, one typical student (Student B) did not have a MUST score at the end of the quad course but did have a three point improvement on their TOLT scores. During the semester, there was a two percentage point improvement on exam one, while quiz scores increased by three points. The greatest improvement was on exam two with a 15% increase. Student B gave credit for the improvement to the intervention professor for going over how to do problems step-by-step, as well as learning how to study more effectively. This student also mentioned that the homework helped instill the confidence that was needed in order for them to improve during the next semester.

Finally, there were students who had excellent participation during the intervention course. These students were typically in class every day, answered questions during class, took careful notes, attempted problems by themselves at times before the professor explained them, finished homework assignments, double-checked answers with tutors or instructors, and attended office hours, or stayed after class to ask questions. As an example, Student C did not improve on their TOLT assessment, yet was able to improve by 40% on their MUST assessment. During the spring semester, there was a 40% improvement on Exam 1 and a seven point improvement on both Quiz 1 and 3. On Exam 2, there was a 60% improvement in their score from the fall semester. Student C credited their improvement to having instructors help guide them through tough problems during tutoring and office hours. In addition to this, Student C learned essential study and problem-solving skills that they were able to apply to multiple problems. They also commented on the benefit of class work in which they were able to work independently to assess their knowledge as a way to find gaps in their understanding. Lastly, the practice exams that were given during the intervention course helped instill the confidence that they needed for future success.

Discussion

Science professors can support students in developing quantitative literacy by emphasizing all of the skills of the discipline in science, which includes problem-solving and math skills. Teachers can help support students by making sure that they are teaching problem-solving skills instead of steering students away from more difficult problems due to the amount of content they must cover (Blackwell et al. 2007; Blonder & Mamlok-Naaman, 2019). By encouraging problem-solving skills and discouraging the memorization of example problems, which can be done incorrectly, students are more likely to increase their quantitative literacy (Becker & Towns, 2012). At the classroom level, each instructor can help encourage quantitative literacy skills by emphasizing math skills and problem-solving skills along with content that will help more students remain as STEM majors.

This study explored the effectiveness of an intervention that aimed at fostering students' quantitative literacy as a way to aid their success in general chemistry courses. Below are the research questions that grounded the study followed by the answers that were found based on the data collected during the intervention course as well as during the following semester.

What is the level of quantitative literacy and reasoning levels both before and after an intervention for STEM majors who have not been successful in the first half of a general chemistry course?

The level of quantitative literacy of students in the intervention course was measured by the MUST assessment at the beginning and the end of the intervention. Improvements in students' math scores is a measurement of growth in their quantitative literacy. According to De Pilar Albaladejo et al., (2018) there is a link between how well students perform on a MUST assessment and how they will do in chemistry classes. Most students scored below 50% on the MUST during week 1 of the intervention, but after the intervention, students were able to increase their average score to 70% which showed a growth in quantitative literacy skills.

In contrast, the reasoning levels of students as measured by the TOLT assessment at the beginning and the end of the intervention showed no significant improvement. Even though reasoning levels can correlate with the integration of math in science as seen in Alivio et al.

(2018), it seems as though the intervention course did not result in a significant increase in students' reasoning skills, but did have a positive impact on their problem-solving techniques toward chemistry problems as seen in exam score improvements the following semester. During the intervention course, problem-solving techniques using conversions and algebra were emphasized rather than proportions and probability tasks commonly seen in the TOLT. These differences could which could account for the difference in achievement between the two assessments, with improvement on the MUST, but not on the TOLT, so the TOLT may not have been the best choice as an assessment tool.

What are the students' confidence levels toward using math skills in a science context both before and after an intervention?

At the beginning of the intervention, students indicated that their confidence levels were low, which they attributed to their lack of study skills and not knowing how to problem-solve. However, by the end of the intervention course, most students indicated that they have gained some confidence in chemistry, which they attributed to teacher explanations, group work, and immediate feedback from instructors. Overall, this showed that students' confidence levels can improve within weeks by creating a classroom environment in which students feel comfortable in groups and are able to ask questions to their instructor so that feedback can be used to improve their skills, which resulted in improved confidence.

What is the effectiveness of teaching students about quantitative literacy, reasoning skills, and study skills on student achievement during the intervention course as well as when retaking chemistry?

With respect to student achievement before and after the intervention, students were able to achieve higher scores during the spring semester when they retook the class as compared to the fall semester when they entered the class for the first time. The exam and quiz averages all showed a statistically significant improvement indicating that teaching students about problem-solving, reviewing math skills, and improving students' confidence levels toward challenging problems did improve their achievement in general chemistry I the following semester.

Limitations of the Study

Limitations of the study include several factors. First, the sample size was small (n=17), as this intervention course was not required for students to retake chemistry the following semester. During the spring there were four students who did not take the intervention course but retook the first semester of general chemistry they were not tracked in our study due to our IRB limitations. The additional ten students who could have entered the intervention course either dropped chemistry or stayed in the chemistry class to retain their full-time student status were also not tracked in this study. Having a larger sample size of students in the intervention course would be needed to confirm that the statistically significant improvements that were made during the retake semester are due to the intervention course. Second, this intervention course was taught to meet the specific needs of these particular students based on what was observed in the classroom and on formative assessments. With more opportunities to teach this course, a more formal framework on what needs to be in the intervention will be established from the beginning which could lead to more improvement.

Future Research

An additional study comparing the scores of the students who retook the class in the spring semester without the intervention should be conducted to serve as a control group for comparison to the students who took the intervention course. This study could determine the effectiveness of the intervention in addition to improvement based on simply hearing the material a second time. Lastly, tracking students who did participate in the intervention but then decided not to continue as STEM majors would be necessary to conduct another study to determine whether 1) if the skills learned in the intervention course transfer to other courses and 2) the impact the intervention course made on their decision to leave the STEM major.

Conclusion

The introduction of an 8-week intervention course for students that were at risk of failing their first semester of general chemistry gave students an opportunity to focus on improving their math skills, problem-solving skills and study skills. As a result of this intervention course, students were able to show statistically significant improvement when they retook their first semester of general chemistry the following semester. Students also came away from the course with increased confidence toward solving chemistry problems. This is a call for instructors to integrate subject-specific tasks that require math and problem-solving skills into the classroom, as well as to continue to support the practice of math skills, problem solving skills, and study skills and to instill confidence in students. We encourage those with the power to make decisions at the institutional level to consider creating courses that will help students develop quantitative literacy skills in order to close achievement gaps in STEM majors.

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Appendix A:
Math-Up Skills Test (MUST) Version A

PRINT: Last name: ______________________________ **First name:** ________________

You have 15 minutes to complete this quiz.

You **may** use a calculator or any other electronic device. Show any needed work on this paper.

Multiply: **1.** $\begin{array}{r} 78 \\ \times 96 \\ \hline \end{array}$

2. $(0.50 \times 10^{-6})(6.4 \times 10^{21}) =$ ____________________

3. $(2.50 \times 10^{-9})(3.0 \times 10^{17}) =$ ____________________

Write these answers in decimal notation (as regular numbers/not fractions).

4. $\frac{140}{10{,}000} =$ ________ **5.** $47^0 =$ _____ **6.** $\frac{\frac{1}{4}}{\frac{1}{2}} =$ ________

Simplify: **7.** $\frac{10^5 \times 10^{23}}{10^{-1} \times 10^{-6}} =$ ____________ **8.** $\frac{9.0 \times 10^{-18}}{2.0 \times 10^{-5}} =$ ____________

Write these values as their decimal equivalents:

9. $\frac{1}{8} =$ ____________________ **10.** $\frac{1}{50} =$ ____________________

11. If $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ then solve for T_2, in symbols as one simple fraction: T_2 **=**

Determine the base-10 log of: **12.** 1000 = _____ and **13.** 0.001 = _____

Solve questions **14** and **15** and write answers in scientific notation.

14. $(3.0 \times 10^{-7})^2 =$ ____________________ **15.** $\sqrt{64 \times 10^{-12}} =$ ____________________

16. If A = B, evaluate: $\frac{A}{A - B}$ ____________ **17.** Simplify: $\frac{25}{25 - 5}$ ____________

18. Circle equivalents of one-thousandth: 10 0.1 0.001 10^{-3} 0.01 1000 $\frac{1}{10^3}$ $\frac{1}{1000}$

Enter the remaining coefficients that balance these chemical equations.

19. **4** NH_3 + ______ O_2 → ______ NO + _____ H_2O

20. **12** NH_3 + ______ O_2 → ______ NO_2 + _____ H_2O

Appendix A:
Math-Up Skills Test (MUST) Version B

PRINT: Last name: ____ **First name:** ____________________

You have 15 minutes to complete this quiz.

You **MAY** use a calculator or any other electronic device. Show needed work on this paper.

Multiply 1. 78×96

2. $(0.50 \times 10^{-6})\ (6.4 \times 10^{21})$ = ________________________

3. $(2.50 \times 10^{-9})\ (3.0 \times 10^{17})$ = ________________________

4. Write these answers in fixed decimal notation (as regular numbers).

a. 140/10,000 = _____ b. 47^0 = _____

Simplify:

5. $$\frac{10^5 \times 10^{23}}{10^{-1} \times 10^{-6}} =$$

6. $$\frac{9.0 \times 10^{-18}}{2.0 \times 10^{-5}} =$$

Write these values as their decimal equivalents:

7. 1/8 = ________________________ 8. 1/50 = ________________________

9. If $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ then solve for T_2, in symbols as one simple fraction: T_2 =

10. Determine the base 10 log of: 1000 = _____ and 0.0001 = _____

11. $(3.0 \times 10^{-7})^2$ = ________________________

12. The square root of 64×10^{-12} = ________________________

Enter the remaining coefficients that balance these chemical equations:

13. **4** NH_3 + ______ O_2 → ______ NO + _____ H_2O

14. **12** NH_3 + ______ O_2 → ______ NO_2 + _____ H_2O

Appendix B:

Test of Logical Thinking Assessment (TOLT)

Name:____

Logic Survey for Visual and Spatial Learning

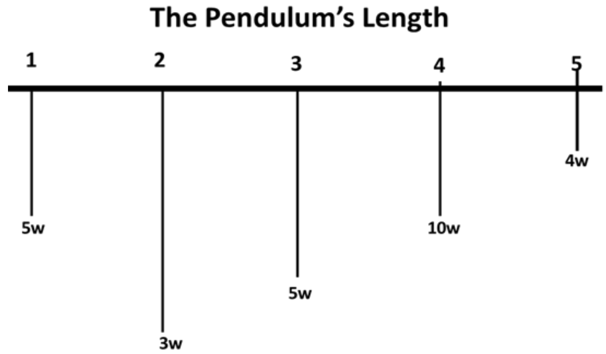
1. Four large oranges are squeezed to make six glasses of juice. How much juice can be made from six oranges?
    a. 7 glasses
    b. 8 glasses
    c. 9 glasses
    d. 10 glasses
    e. Do not know

    Reason:
    1. the number of glasses compared to the number of oranges will always be in the ratio of 3 to 2.
    2. with more oranges the difference is less
    3. the difference between the numbers will always be two
    4. with four oranges the difference was 2 with six oranges the difference would be 2 more
    5. there is no way of knowing

2. How many oranges are needed to make 13 glasses of juice?
    a. 6 and ½ oranges
    b. 8 and 2/3 oranges
    c. 9 oranges
    d. 11 oranges
    e. Do not know

    Reason:
    1. the number of glasses compared to the number of oranges will always be in the ratio of 2 to 3.
    2. if there are seven more glasses, then five more oranges are needed
    3. the difference between the numbers will always be two
    4. the number of oranges will be half the number of glasses
    5. there is no way of predicting the number of oranges

Use the figure below to answer Questions 3 and 4:



3. Use the figure to the right to answer the question: Suppose you wanted to do an experiment to find out if changing the length of a pendulum changed the amount of time it takes to swing back and forth. Which pendulums would you use for the experiment?
    a. 1 and 4
    b. 2 and 4
    c. 1 and 3
    d. 2 and 5
    e. All
    f. Do not know

    Reason:
    1. the longest pendulum should be tested against the shortest pendulum
    2. All pendulums need to be tested against one another
    3. As the length is increased the number of washers should be decreased
    4. the pendulums should be the same length but the number of washers should be different
    5. the pendulums should be different lengths but the number of washers should be the same

4. Suppose you wanted to do an experiment to find out if changing the weight on the end of the string changed the amount of time the pendulum takes to swing back and forth. Which pendulums would you use for the experiment?
    a. 1 and 4
    b. 2 and 4
    c. 1 and 3
    d. 2 and 5
    e. All
    f. Do not know

    Reason
    1. the heaviest weight should be compared to the lightest weight
    2. All pendulums need to be tested against one another

3. as the number of washers is increased the pendulums should be shortened
4. the number of washers should be different but the pendulums should be the same lengths
5. the number of washers should be the same but the pendulums should be different lengths

5. A gardener bought a package containing 3 squash seeds and 3 bean seeds. If just one seed is selected from the package, what are the chances that it is a bean seed?

    a. 1 out of 2
    b. 1 out of 3
    c. 1 out of 4
    d. 1 out of 5
    e. 4 out of 6
    f. Do not know

    Reasons:
    1. Four selections are needed because the three squash seeds could have been chosen in a row.
    2. There are six seeds from which one bean must be chosen
    3. one bean seeds to be selected from the total of three
    4. one half of the seeds are bean seeds
    5. In addition to the bean seed, three squash seeds could be selected from a total of six

Use the following information to answer question 6:
A gardener bought a package of 21 mixed seeds. The package contents are listed below:

3 short red flowers
4 short yellow flowers
5 short orange flowers
4 tall red flowers
2 tall yellow flowers
3 tall orange flowers

6. If just one seed is planted, what are the chances that the plant that grows will have red flowers?

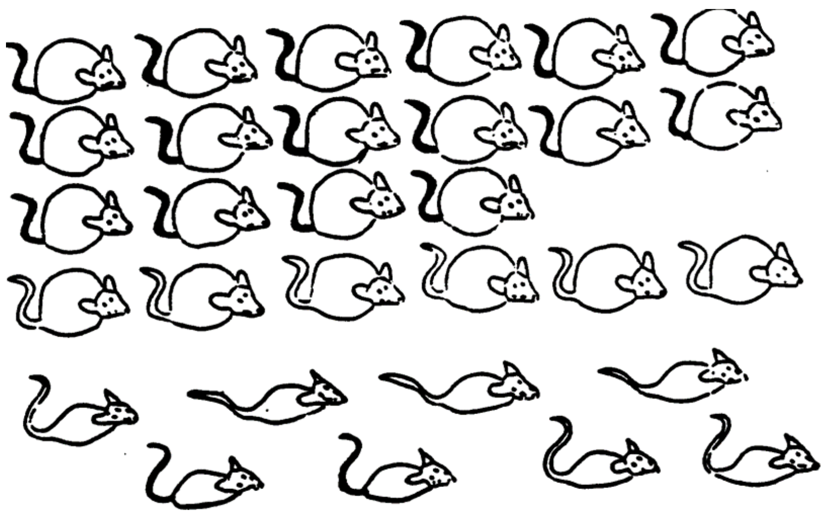
    a. 1 out of 2
    b. 1 out of 3
    c. 1 out of 7
    d. 1 out of 21
    e. Other
    f. Do not know

Reasons

1. one seed must be chosen from among those that grow red, yellow, or orange flowers
2. 1/4 of the short and 4/9 of the talls are red
3. It does not matter whether a tall or short flower is picked. One red seed needs to be picked from a total of seven red seeds
4. one red seed must be selected from a total of 21 seeds
5. 7/21 seeds will produce red flowers

7. The mice shown represent a sample of mice captured from a part of a field. Are fat mice more likely to have black tails and thin mice more likely to have white tails?

   a. Yes
   b. No

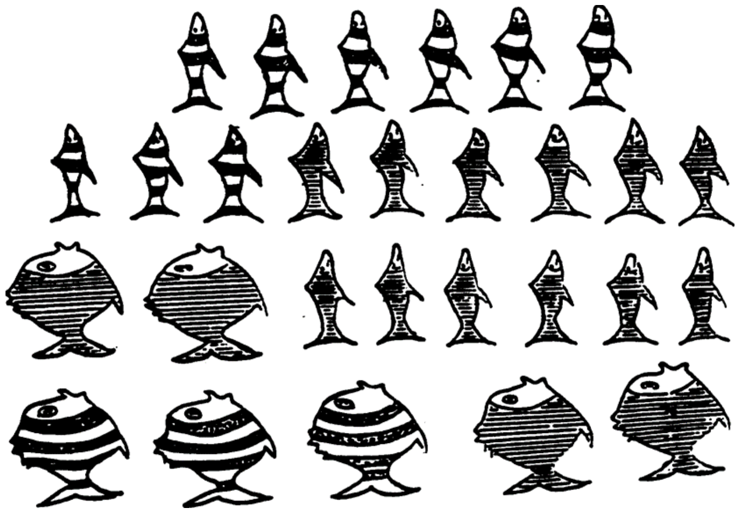


Reason

1. 8/11 of the fat mice have black tails and 3/4 of the thin mice have white tails
2. Some of the fat mice have white tails and some of the thin mice have white tails
3. 18 mice out of 30 have black tails and 12 have white tails
4. Not all of the fat mice have black tails and not all of the thin mice have white tails
5. 6/12 of the white tailed mice are fat

8. Are fat fish more likely to have broad stripes than thin fish based on the image below?

   a. Yes
   b. No



Reason

1. Some fat fish have broad stripes and some have narrow stripes
2. 3/7 of the fat fish have broad stripes
3. 12/28 are broad stripes and 16/28 are narrow striped
4. 3/7 of the fat fish have broad stripes and 9/21 of the thin fish have broad stripes
5. some fish with broad stripes are thin and some are fat

9. Three students from grades 10, 11, and 12 were elected to the student council. A three-member committee is to be formed with one person from each grade. All possible combinations must be considered before a decision can be made. Two possible combinations are Tom, Jerry and Dan (TJD) and Sally, Anne, and Martha (SAM). List all other possible combinations in the space provided.

Grade 10	Grade 11	Grade 12
Tom (T)	Jerry (J)	Dan (D)
Sally (S)	Anne (A)	Martha (M)
Bill (B)	Connie (C)	Gwen (G)

10. In a new shopping center, 4 store locations are going to be opened on the ground level. A barber shop (B), a Discount Store (D), a Grocery Store (G) and a Coffee Shop (C) want to move in there. Each one of the stores can choose any one of four locations. One way that the stores could occupy the 4 locations is BDGC. List all other possible ways that the stores can occupy the 4 locations in the space provided.

Appendix C:

Class Confidence Survey

Week 4 Confidence Survey

On a Scale of 1-5. 5 being I am an expert that can teach it to someone else and 1 being I did not get it at all.

How well did you understand conversions BEFORE entering this class

On a Scale of 1-5. 5 being I am an expert that can teach it to someone else and 1 being I did not get it at all.

How well did you understand conversions CURRENTLY

What in class supports do you need in order to improve your rating?

What outside of class supports do you need to improve your rating?

What were the most helpful and least helpful activities in helping you learn conversions? State why in your response.

___________ was the most helpful activity because.....

___________ was the least helpful activity because......

Examples of activities:

Teacher Explanations

Small group work with neighbors

Small group work with tutors/ instructors

Homework and individual practices

Study Skill Tips

If you have a specific example please feel free to add it

Week 8 Confidence Survey

During my chemistry class at the beginning of the semester my biggest struggles were ___________ because_______

The most valuable lesson and or skill that I learned from this class that can help me in other classes or retaking chemistry in the future is ___________

My chemistry knowledge has improved with this class 5- I am doing well enough that I can tutor someone else

4- I am getting almost all problems correct

3- I am getting more problems correct

2- I am doing about the same

1- not at all

The activities that has helped my chemistry knowledge the most are ______ because ______

Examples of activities:

Teacher Explanations

Small group work with neighbors

Small group work with tutors/ instructors

Homework and individual practices

Study Skill Tips

If you have a specific example please feel free to add it

My problem solving skills have improved with this class

5- I am doing well enough that I can tutor someone else

4- I am getting almost all problems correct

3- I am getting more problems correct

2- I am doing about the same

1- not at all

The activities that has helped my problem solving skills the most are ______ because ______

Examples of activities:

Teacher Explanations

Small group work with neighbors

Small group work with tutors/ instructors

Homework and individual practices

Study Skill Tips

If you have a specific example please feel free to add it

My confidence level in performing math and chemistry problems have improved with this course

5- I am very confident now

4- I am confident most of the time

3- I have gained some confidence

2- I have gained very little confidence

1- I have not gained confidence

The activities that has helped improve my confidence levels the most are ______ because ______

Examples of activities:

Teacher Explanations

Small group work with neighbors

Small group work with tutors/ instructors

Homework and individual practices

Study Skill Tips

If you have a specific example please feel free to add it

In your opinion what can be done to improve the course so you are ready for chemistry?

Is there anything that you wish we would have done during this quad course?