

Instructional Support Sessions in Chemistry: Alternative to Remediation

By Tiffany L. Hesser and Jess L. Gregory

ABSTRACT: *A lack of college readiness can affect student success in the classroom and impact retention rates. It has been recommended that all students be placed in courses with college-level content but that added support be provided for students identified as underprepared. This study examines the impact of added instructional time and support embedded within a college-level chemistry course for students who tested below college level in math. The results indicate that weekly instructional sessions for students identified as academically underprepared can help them achieve course outcomes indistinguishable from those of their college-ready peers.*

College-ready students are able to understand what is expected in a college course and can benefit from the course's intellectual lessons. College readiness encompasses a range of behaviors that reflect a high level of self-awareness, self-monitoring, and self-control as well as effective study behavior and study skills. Therefore, college readiness can be considered in terms of intellect, mindset, and disposition (Conley, 2007).

It is beneficial to all stakeholders that students enter institutions of higher education ready for college. Lack of readiness can affect student success in the classroom and even impact students' levels of self-esteem (Venezia, Kirst, & Antonio, 2004). Student readiness may also impact retention rates, because institutions that do not adequately address college readiness can experience a decrease in retention rates for students (Chan, 2013). If students enter postsecondary institutions underprepared, then these students' deficits need to be remediated efficiently and effectively.

Many postsecondary institutions offer remedial courses in mathematics, reading, and writing, and some institutions also offer developmental courses in chemistry. Many topics addressed in a first-year chemistry course require the application of algebraic functions, are analytical in nature, and require skills that only some students have as they enter college. Placement in remedial chemistry courses may be based on Math SAT scores because students identified as underprepared in mathematics may not be able to complete the

calculation-based components of a college chemistry course.

A large, 6-year study completed at Texas Tech University involved almost 6,000 students and assessed the effectiveness of a chemistry remediation course. The results indicated that students identified as underprepared performed comparably to their college-ready peers with and without remedial interventions (Bentley & Gellene, 2005). High attrition rates have been noted for such courses, leading researchers to suggest that institutions must carefully consider whether remedial courses in chemistry are worth the cost of institutional resources and delayed academic programs (Bentley & Gellene, 2005; Jones & Gellene, 2005). If remedial courses are not provided, it is important to ensure that students identified as underprepared can be supported academically in other ways.

Numerous interventions have been employed to build underprepared students' academic skills. For example, direct instruction and mastery learning have both been promoted as successful strategic approaches to address learning for students underprepared for college-level coursework. Direct instruction incorporates a seven-step approach that moves students through stimulus control, reinforcement, and modeling; in this approach, practice activities are given to students during class sessions to assist them in developing mastery of content taught (Aguete, Ojugo, & Imhanlahimi, 2010). Mastery learning, the process of presenting students with small units of instruction with frequent testing to demonstrate mastery, has been recommended because it has been linked to an increase in course completion, higher grades, and higher levels of retention for students in remedial programs (Boylan, Bonham, Claxton, & Bliss, 1992; Boylan & Saxon, 1998).

In addition, supplemental instruction and small-group study sessions have shown to be effective techniques for students in remedial courses and were found to have positive impact on student scores (Boylan & Saxon, 2005; Martin & Arendale, 1994; Moore & DeLee, 2006; Ogden, Thompson, Russell, & Simons, 2003). Student leaders who have already completed the courses can successfully run supplemental instruction sessions. It is

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important to note that student leaders or tutors working with students in remedial courses must be trained properly in order to effectively support learning (Boylan, Bonham, Claxton, & Bliss, 1992; MacDonald, 1994). A format of small study groups and added study time has been recommended for students requiring remediation in higher education and supported by studies in which students enrolled in courses accompanied by instructional support consistently outperformed students in more traditional courses (Boylan & Saxon, 2005; Martin & Arendale, 1994; National Conference of State Legislatures, 2012).

The National Conference of State Legislatures' (2012) publication on reforming remedial education recommended added levels of support in the form of tutoring. Boylan and Saxon (2005) made similar recommendations but insisted that tutors must be carefully chosen, prepared, and trained, because training "contributed to increased effectiveness of individual program components such as instruction, counseling, and tutoring as well as to overall program effectiveness" (p. 8).

Strategic learning is also an important learning tool for students in college. Students are often unaware of how to obtain and process information presented and must be taught how to think strategically (Weinstein, 1982). Additionally, students identified as underprepared are often unaware of their own limitations as students and need to learn how to consider their own learning process through a metacognitive approach (Hoffman & McGuire, 2010; Kruger & Dunning, 1999). Strategic learning supports students by presenting and reinforcing the skills, attitudes, and beliefs that lead to success.

Faded worked examples are one strategy especially useful in problem-solving courses. Worked examples provide students with a problem, the steps needed to complete the problem, and a solution, with explanations for steps in the overall process. Faded worked examples are similar to worked examples, but steps are faded out and completed by the student with an explanation of procedural importance of each step. Although worked examples have contributed to the mastery of science problem solving (Taconis, Ferguson-Hessler, & Broekkamp, 2001), researchers have indicated the fading of the worked examples can further influence student learning and ensure that students understand procedural concepts rather than memorizing a process (Cracolice, Deming, & Ehlert, 2008; Crippen & Brooks, 2009; Moreno, Reisslein, & Delgoda, 2006; Sweller & Cooper, 1985).

Focus of Inquiry

The purpose of this study was to examine the impact of added instructional time and support embedded within a college-level chemistry course for students identified as academically underprepared

in math. Within the scope of this study college readiness was determined using math proficiency on a standardized precollege measure and did not focus on mindset or disposition of students. The research question for this study was as follows: With instructional sessions providing embedded support in general chemistry, can students identified as academically underprepared in mathematics experience levels of achievement comparable to those of students identified as college ready?

Method

This quasi-experimental study utilized a quantitative method approach using data collected from a convenience sample of nonequivalent groups that included all of the students enrolled in a large first-year course in general chemistry. This study focused on students' academic success within an intervention course designed with embedded support in the form of added instructional time and support from Teaching Assistants (TAs). The study was conducted within a single semester in Fall 2014

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and utilized common questions throughout the course and a common final assessment to compare achievement levels of students identified as underprepared for college chemistry to a comparative sample of college-ready.

Course Development

A new course was developed to accommodate students identified just below college level in math using current placement exams. This course was labeled General Chemistry with Instructional Support or General Chemistry-IS. The General Chemistry-IS course covered typical content taught in a freshman-level chemistry course but was designed with additional instructional time for students identified as academically underprepared for chemistry. Students enrolled in General Chemistry-IS were required to attend weekly instructional sessions that added 1.25 hours to the weekly course time. Instructional support sessions were organized to reinforce lecture content and provide extra practice time for students. In a format recommended by research to support student achievement (Boylan & Saxon, 2005; National Conference of State Legislatures, 2012), each session was led by a TA working with small groups of 12 students (maximum). The sessions

focused primarily on problem-solving approaches and practice problems that covered typical course content including those provided by the textbook.

Prior to the start of the semester, TAs participated in an initial 15-hour training period provided by the Director of the Center for Learning Resources. Thirteen hours of training covered materials and a training outline available from the College Reading and Learning Association, which has created tutor-training programs in post-secondary educational institutions (see Appendix). TAs were also trained for an additional 2 hours in metacognitive awareness, the role of motivation in learning, and calculation-based problem-solving strategies for chemistry students. These strategies included the use of worked and faded-worked examples.

Instructional Support Sessions and Learning Strategies

General Chemistry is a course that requires mastery of definitions, theoretical concepts, and analytical problem solving. Because general chemistry content is algorithmic in nature, instructors often incorporate math and problem-solving strategies. The instructional sessions required for students identified as underprepared for chemistry focused mostly on worked examples and faded worked examples, as described previously. Problem sets were created for each instructional session and were designed to support content presented in class and text.

Sample and Participant Selection

Students intentionally placed in the program were those identified by the university as just below college level in math performance in order to ensure the lowest level of academic risk for the students involved. Academic readiness for the college-level chemistry course was determined using math placement scores. Students who placed into College Algebra using the math placement exam in previous semesters would have been placed into a remedial chemistry course, but in the semester of this study they were considered to be candidates for the new course and enrolled in General Chemistry-IS. These students would be learning algebra concurrently with the chemistry course. Students who placed higher than College Algebra, into Precalculus or Calculus 1, were identified as academically college-ready in terms of their chemistry placement. These students became the comparison group within this study. Students who placed lower than College Algebra were not involved in the study and, since they had not demonstrated algebraic skills at a level needed for the course, were not permitted to enroll in General Chemistry until completion of remedial math courses.

This placement process resulted in 300 students identified as college-ready enrolled in five sections of General Chemistry taught by four different instructors. Another 100 students were identified as academically underprepared in math and were therefore enrolled in three sections of General Chemistry-IS taught by two different instructors. Students enrolled in General Chemistry-IS were required to participate in the support sessions embedded within the chemistry course.

Data Collection

Introductory surveys were distributed on the first day of class to all participants in the study. These were used to obtain self-reported demographic data from all students in General Chemistry and General Chemistry-IS sections: major, current standing, age, previous high school experience and state, and other courses in which they were enrolled. Data were also obtained through university records for incoming freshmen regarding their math placement score and SAT scores. The study was done with consent forms and IRB approval for all surveys and data obtained.

To evaluate achievement for both populations enrolled in the general chemistry courses, a series of questions was developed to be administered as part of course exams; these were multiple-choice questions with four possible responses for each question. Common questions relevant to the material covered were placed on each exam (Exam 1, 2, and 3) for a total of 14 questions. These questions were identical for all students in General Chemistry and General Chemistry-IS, and throughout the semester the results were recorded on a dichotomous scale.

The final exam was created and provided by the chemistry department. The final exam consisted of 45 questions that focused on both

calculations and concepts. There were 25 multiple-choice questions and 20 open-ended questions. Open-ended questions were allowed partial-credit grading by instructors for course grades, but, for assessment purposes in this study, results were recorded for every student on a dichotomous scale. This was done to ensure consistency in the data, because partial credit was subjective and based on instructor opinion.

Analysis and Results

Information from the introductory surveys provided an overview of the sample groups and allowed for a more accurate response to the current research question, should trends or abnormalities be seen in the data obtained. The self-reported data indicated that 83.5% of the student groups in the study sample considered themselves at the freshman level. Sophomores made up 8.5% and juniors and seniors made up 2.3% of the sample. In the underprepared sample of students, 94.6% were under 20 years old, and 86.8% of the college-ready sample was under 20 years old. In the underprepared sample of students, 48.9% were female and 50.0% were male. In the college-ready population, 51.3% were female and 40.0% were male. In Fall 2014, a majority of students enrolled were science majors and reported their academic major when entering the course.

Self-reported results further indicated that 98.2% of the students enrolled were currently identified as full-time students. This included 98.0% of the underprepared sample and 97.1% of the college-ready sample. Of these full-time students, 9.8% were enrolled in an additional three courses, 55.3% were enrolled in an additional four courses, 24.2% were enrolled in an additional five courses, and 4.3% reported being enrolled in six to seven courses in addition to General Chemistry.

The final, exact enrollment at the start of the semester was 399 students. Six different instructors taught the students enrolled in General Chemistry in Fall 2014 (eight sections), who constituted 76.2% of the students. Two instructors taught the students enrolled in General Chemistry-IS (three sections), for students identified as underprepared for General Chemistry, who constituted 23.8% of the students in the course at the beginning of the semester.

It is the policy of the chemistry department that students are permitted to withdraw from chemistry courses until the final exam period. Of the 399 initially enrolled, only 318 students persisted throughout the course and participated in the final exam: 69 students were in General Chemistry-IS, and 249 were in the regular General Chemistry course. Analyses were conducted on data of only the students who persisted throughout the entire semester, to more closely examine the academic progress of students participating in all 14 weeks of instructional support sessions.

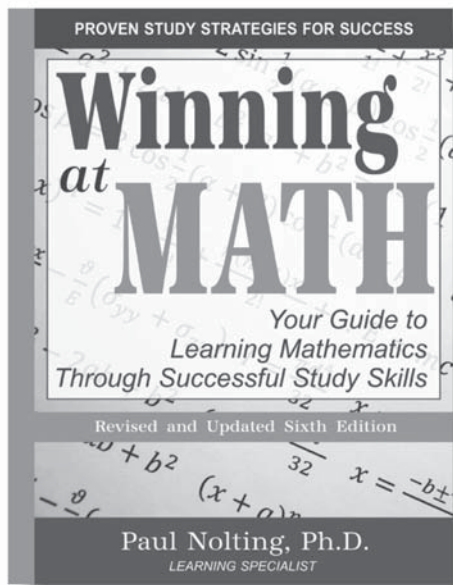
To confirm that the two groups of students were nonequivalent when entering the course, math placement exam scores, Math SAT scores, and Verbal SAT scores were compared. Means of the scores of the two student groups were significantly different in all three assessments. Math placement scores for underprepared students ($M = 52.88$, $SD = 13.73$, $N = 58$) and college-ready students ($M = 87.14$, $SD = 13.73$, $N = 212$) were determined to be significantly different using an independent-sample t -test, $t(268) = -14.66$, $p < .001$. SAT math scores were also analyzed for underprepared students ($M = 538.7$, $SD = 57.61$, $N = 51$) and college-ready students ($M = 568.0$, $SD = 70.07$, $N = 205$) and were determined to be significantly different using an independent-sample t -test, $t(254) = -2.76$, $p < .05$. Finally, SAT verbal scores analyzed for underprepared students ($M = 509.2$, $SD = 71.68$, $N = 51$) and college-ready students ($M = 534.0$, $SD = 69.01$, $N = 205$) were determined to be significantly different using an independent-sample t -test, $t(254) = -2.27$, $p < .05$. Overall, the analysis of entrance exam scores indicated that students labeled as underprepared had entrance assessment averages significantly lower than the averages of college-ready students when entering the General Chemistry course. These results confirmed a lower level of math proficiency and supported the placement of these students into a course with added instructional support.

To answer the research question, common question results were analyzed for underprepared and college-ready students who completed the course. The analysis was done to examine overall student performance but also evaluate any comparative trends in performance as the semester progressed. To examine this aspect of student performance, the 14 common questions were broken

Table 1
Assessment Scores on Grouped Common Questions

	<i>N</i>	Average Correct Responses	Std. Deviation	<i>t</i> (<i>df</i>)	Sig. (2-tailed)
Group 1 CQ Underprepared	69	2.91	1.43	-4.43 (316)	.000
Group 1 CQ College-ready	249	3.66	1.18		
Group 2 CQ Underprepared	69	2.23	1.14	-1.90 (316)	.057
Group 2 CQ College-ready	249	2.54	1.19		
Group 3 CQ Underprepared	67	2.90	0.78	12.1 (256)	.000
Group 3 CQ College-ready	191	1.62	0.73		
All CQ Underprepared	69	7.96	2.05	1.69 (316)	.093
All CQ College-ready	249	7.44	2.32		

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up into three groups and analyzed comparatively based on the number of correct responses. The first set of questions was given early in the semester and covered topics from Chapters 1, 2, and 4 of the assigned text. The second set of questions was given to all students midsemester and consisted of topics covered approximately 6 to 8 weeks into the course. These questions were drawn from Chapters 5, 6, and 7. The third set of questions covered content discussed toward the end of the semester and was given just prior to the final exam. This set consisted of common questions from Chapters 8, 9, and 10. The third set of questions was not given to all college-ready students ($N = 191$ rather than $N = 249$) because some instructors did not complete an additional assessment just prior to the final exam. The results and independent sample t -test results can be found for this analysis in Table 1 (p. 24).

Even though students identified as underprepared had significantly lower mean correct responses than college-ready students on Group 1 common questions, by midsemester there was no significant difference between mean correct responses for the student groups on Group 2 common questions. On the last set of common questions given just prior to the final exam, the mean score of correct responses of the students identified as underprepared was significantly higher than the mean score of the college-ready students. The percent correct means for all common questions

were graphed for both student groups (see Figure 1).

Final exam responses were also analyzed for students identified as underprepared and college-ready who completed the course. The analysis was done to compare the multiple-choice questions and open-ended questions separately. In a comparison

of these two portions of the final exam, it was found that the mean values were not normally distributed. The normality violation was considered to be nonproblematic due to the large sample size ($N = 318$), and data were obtained for the t -test without the assumption of equal variances.

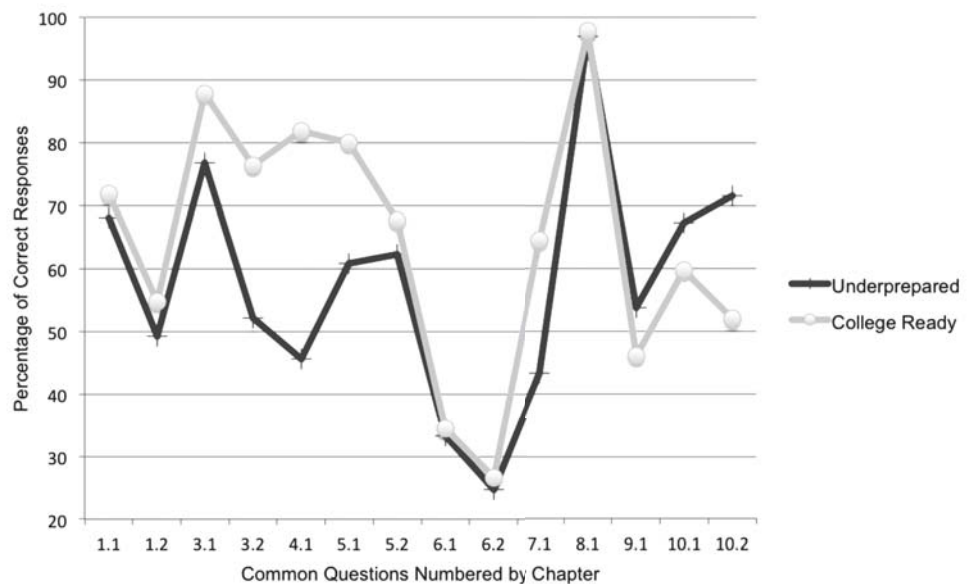


Figure 1. Trends in mean correct responses on common test questions, graphed for students identified as underprepared and college-ready. The graph indicates that the percent of correct responses increases as the semester progresses for students identified as underprepared.

In a comparison of mean correct responses of the final exam multiple-choice questions for students identified as underprepared and college ready, the results indicated that there was no significant difference in correct response scores for students identified as underprepared and college ready. By contrast, in the comparison of mean correct responses for open-ended questions on the final exam, the results indicated that students identified as underprepared had a significantly higher mean percent correct than college-ready students (see Table 2).

Discussion

Of the 92 students originally identified as eligible for instructional support, 69 persisted and on average achieved results statistically equivalent to or higher than students labeled as college ready. Of the students who did not complete the course, two did not attend a single class and 21 did not complete the course in full. Students who withdrew from the course were asked to identify their reason for withdrawing; eight of these students stated that their grade was too low for them to pass the course, but that they planned to retake the course at a later time. Another seven of these students stated that they had chosen to change their major as a result of the General Chemistry course. Another two of these students claimed that they were currently doing well in the course but had changed their major and no longer needed General Chemistry. These course withdrawals constituted a 25.0% attrition rate for students enrolled in General Chemistry-IS, whereas students enrolled in General Chemistry had a 17.8% attrition rate. In previous years, 13.6% of students withdrew from General Chemistry in Fall 2013 and 12.0% in 2012. This indicated that students enrolled in General Chemistry-IS withdrew from General Chemistry at a higher rate than college-ready students in 2014, 2013, and 2012.

The examination of the persisting students yields information useful for answering the research question. Of the 69 students enrolled in General Chemistry-IS and the 249 students enrolled in General Chemistry, the overall

average response to all the common questions asked throughout the semester indicated no significant difference between the two groups of students. When further analysis was completed to examine the change in scores over the course of the semester, it was determined that the students identified as underprepared did score lower on the questions covering content addressed early in the semester. This validates these students' need for added instructional support. After exposure to the embedded support sessions for approximately 6 weeks, the students identified as underprepared had scores not significantly different from the scores of the other students on questions that covered content addressed midsemester. As the semester progressed, and exposure to embedded support continued for approximately 12 weeks, the students identified as underprepared actually had mean correct responses on common questions statistically higher than the mean scores of college-ready students for material covered late in the course. These findings suggest that the students

The embedded support designed for this study provided adequate instructional support as evidenced by the academic achievements of the students.

who were enrolled in the instructional support sessions for the semester were able to increase their success on the common exam questions so as to score comparably to college-ready students. As the semester progressed, the underprepared student population slowly increased their performance on the common questions. By the end of the semester, students who were identified as underprepared for the course just 12 weeks earlier were outperforming their college-ready peers on the common exam questions.

This pattern of scores was also found on the final exam, where results indicated that students identified as underprepared scored as well as their college-ready peers. Mean correct responses to the 25 multiple choice questions indicated no significant difference between the two groups of students. Underprepared students performed slightly higher on the mean correct responses to the open-ended questions.

The question for this study was whether the academic achievement of the students considered unprepared for General Chemistry could be improved to the academic level of their college-ready peers. After 14 weeks of working with TAs in regularly scheduled instructional sessions, students identified as underprepared successfully completed the General Chemistry course with scores consistent with those of students identified as college-ready.

Bahr (2010) observed that students who remediate successfully and attain college-level skills can experience academic outcomes similar to those of their college-prepared peers. The embedded support designed for this study provided adequate instructional support as evidenced by the academic achievements of the students enrolled in General Chemistry-IS by the end of the semester.

Limitations

As with any study, there are limitations. This study focused on students identified as underprepared in math at a single institution; academic achievement may be measured differently elsewhere. Moreover, placement into remedial chemistry at this institution is based on placement into mathematics and does not consider high school completion of chemistry coursework.

The study design also limits conclusions to be drawn. Students were not randomly assigned to treatment groups; rather, the study focused on a convenience sample of approximately 350 students, taught by six different instructors in eight different sections of the course. Differences among instructors can also be confounding variables; in fact, it is possible that success of students in the General Chemistry-IS sections may be due to superior teaching in these sections, and future studies should look for instructor effects by switching these instructors to regular sections.

Some instructors may have made recommendations for study strategies outside the course. These variables were not controlled. Nor were students from either group prevented from seeking support outside the instructional sessions with peer tutors provided by the university or at the Center for Learning Resources, where professional tutors are available at no cost to students. Therefore, some participants may have had additional support unaccounted for within the study. In addition, the

Table 2
Assessment Scores on Final Exam

	N	Average Correct Responses	Std. Deviation	t (df)	Sig. (2-tailed)
Multiple Choice Underprepared	69	15.20	3.25	0.336 (147.9)	.73
Multiple Choice College-ready	249	15.04	4.50		
Open Ended Underprepared	69	15.62	4.88	2.294 (137.1)	<.05
Open Ended College-ready	249	14.00	6.29		

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design of this study did not permit analysis of which aspects of the treatment were effective.

Data were collected from scores on calculation-based multiple-choice questions created by the textbook publisher so that direct comparisons could be made when analyzing student responses. However, these questions were not verified as valid or reliable in terms of content, and their number may or may not have been sufficient for measuring student achievement.

Moreover, worked and faded worked examples were the main study strategy for problems utilized in the instructional support sessions. Other strategies may have been appropriate for the calculation-based study, but the use of specific strategies allowed for focused, organized instruction within the instructional sessions.

This study focuses on the students' qualifications by math score and does not address the role of mindset and disposition in student success. High levels of motivation, specifically intrinsic motivation, have been linked to academic achievement (Fryer & Elliot, 2007; Pintrich & DeGroot, 1990; Spinath, Spinath, Harlaar, & Plomin, 2006). Self-efficacy, or an individual's judgments of his or her capabilities to perform given actions, may also impact a student's behavior (Bong & Skaalvik, 2003; Schraw, Brooks, & Crippen, 2005; Schunk, 1991). Noncognitive issues should be addressed when working with students identified as underprepared

(Smittle, 2003), and these unidentified issues may have further impacted or clarified results.

Implications for Future Research and Practice

It will be important to determine by future analysis whether the students in the group identified as underprepared for General Chemistry will be successful in the long term as well as in their initial chemistry course. Students identified as underprepared were offered added support and

Educators should consider designing curriculum that includes decreasing levels of support...to incrementally incorporate strategies.

structure to their learning. The subsequent course, General Chemistry 2, does not maintain this same format, so a future study should examine whether students incorporate the academic lessons learned in General Chemistry-IS into later problem-solving courses. All students enrolled in this study will be tracked for their ability to succeed in General Chemistry 2 in Spring 2015.

If these students' initial success is not sustained, then it may indicate that students identified as underprepared need longer-term support for true academic gains. Students might be better served if support services continue to be provided to those initially identified as underprepared in subsequent, higher level courses. Educators should consider designing curriculum that includes decreasing levels of support to assist students to incrementally incorporate strategies over several semesters. This may bolster their transfer of study strategies to other academic settings.

The withdrawal rate of students from General Chemistry-IS was higher than from General Chemistry. It was also higher than withdrawal from General Chemistry in previous fall semesters. Future studies may incorporate interviews with students who withdraw from class and may also track patterns of withdrawal from other courses. It will also be useful to measure long-term success of the two sample groups in their educational careers.

Reproducibility of the study's results is also important for future research. Further studies should be done to verify the outcome of this study and decrease the limitations presented. It is not clear from this study whether the success of students considered unprepared for General Chemistry was due primarily to the content of their additional instruction, additional instructional time, or affective factors related to students' sessions

with TAs. Analysis of multiple and related factors would require a more extensive study. Instructional sessions should be observed or recorded in future studies to verify consistency of instruction. Also, although all TAs were presented with the same training, this study does not describe differences among the skills and understanding of the TAs, nor are these differences considered as factors influencing the results of this study.

In addition to reproducing this study, other researchers may want to extend it. This particular study focused on success in General Chemistry, but the educational strategies utilized may be applied beyond chemistry education to other calculation-based subjects such as mathematics, physics, and engineering.

Conclusion

The goal of this study was to explore the use of instructional support for students identified as academically underprepared and determine if these students could perform at levels comparable to their college-ready peers. At a time when the effectiveness of remedial courses is being questioned and some studies caution against remedial courses in chemistry, it is important to determine whether students identified as underprepared can be successful academically without remedial courses if structured instructional support is embedded in a college-level course. The value of this kind of research is apparent because education reform surrounding remediation in higher education currently recommends integrating students identified as underprepared into courses with college-level content while providing additional support (Bailey, 2009; Complete College America, 2012; Developmental Education Initiative, 2010). These recommendations have affected policy decisions in states such as Connecticut, where policymakers have removed remedial courses from state universities for students considered underprepared at the 11th or 12th grade level. As of Fall 2014, these students were required to enroll in college-level courses, and institutions were expected to provide additional support (State of Connecticut, 2012).

When recommendations and policy changes like these are enacted, it is important to know what constitutes additional support for students identified as underprepared and how such support can be integrated successfully into postsecondary courses. The data from this study indicate that weekly instructional sessions can help students identified as academically underprepared for chemistry to achieve outcomes indistinguishable from those of their college-ready peers. Consequently, these students may proceed directly into college-level courses when entering postsecondary institutions, reducing the time required for degree completion and potentially increasing the likelihood of persistence to graduation.

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