Effect of a Concurrent Enrollment Preparatory Course on Student Achievement and Persistence in General Chemistry

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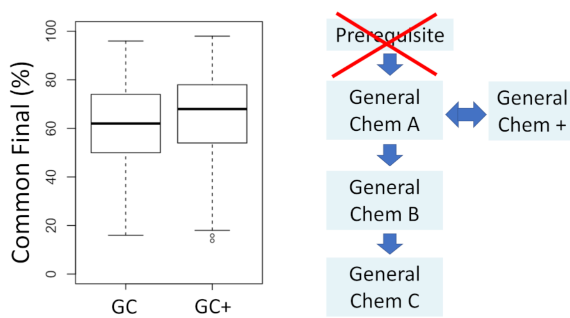
Abstract

A concurrent preparatory course was developed for a university-level general chemistry course to replace prerequisite classes and online exercises implemented in previous years. The concurrent preparatory course was structured with three hours of active learning class time. Lecture content was delivered asynchronously online. Topics were chosen based on fundamental topics needed to succeed in general chemistry. Topics included both those typically found in a preparatory chemistry class as well as some simpler topics being taught in the first course of general chemistry. Two cohorts of students in a program designed to facilitate minoritized student achievement in biological sciences were compared. In the initial year of this study, a prerequisite online homework module was required. In the following year the concurrent preparatory course was required. Students who took concurrent preparatory course did significantly better on the common final exam than those who did not.

Keywords

First-Year Undergraduate / General, Curriculum, Testing / Assessment, Minorities in Chemistry, Collaborative / Cooperative Learning:

Graphical Abstract



Introduction

Higher education is tasked with the challenge of providing equitable access to courses, learning outcomes, and degree completion.[1] Historically, placement tests determined student enrollment into preparatory courses. This costly[2] and time consuming system is intuitive and well intentioned, yet has proven ineffective.

Though many placement methods using mathematical and chemical principles have been developed,[3–5] the complex array of predictive success factors in general chemistry[6,7] lead to expected inaccuracies in placement.[8] Students identified as needing preparatory courses often perform as well as students who are not.[9] Students who disregard preparatory placement and enroll in college-level courses are more likely to pass those courses than the students who initially take the preparatory courses.[10] These inaccuracies create significant retention impacts via increased attrition after the prerequisite course, thereby lowering successful completion of the appropriate college level course.[9,11,12]

Placement testing issues can be reduced by using a variety of placement methods to increase the likelihood that students can place into and complete college level courses.[13] Alternative placing models such as using high school performance markers,[14] direct entry, compressed remediation, first course exams,[15] and tailored remediation courses[2] have attempted to reduce misplacement into preparatory courses.

Solving placement inefficiencies is not the only concern. Preparatory courses do not perform as expected and students would be better served by entering directly into college courses.[2,9,16–20] In addition to the lack of performance increase,[9] students who take preparatory courses are less likely to graduate within six years.[16] In an attempt to counteract this, California State University enacted Early Start, a program requiring students who needed preparatory courses to enroll in courses prior to their freshmen year. However, this showed no improvement when compared to enrollment in the fall or no remediation at all.[17] Other universities have shown evidence of improved learning outcomes with prerequisite summer (early start) courses.[18] Bridging programs that involve only weeks of prerequisite work performed before the quarter have also been implemented. In some cases they have been shown to help students of all incoming backgrounds,[21] but in other cases the bridge programs only helped in cases with small achievement gaps.[19] These interventions did nothing to close larger achievement gaps.[19] Voluntary online homework and preparatory programs have been shown to improve learning outcomes in those who choose to take them.[20] However, because stronger students are more likely to volunteer, these programs do not reach the students who need them most.[20] Solutions using summer programs solve the problem of shifting students off course tracks, but generally with increased cost, administrative burdens, financial aid problems, and difficulties of students being unable or unwilling to participate.

It is important to consider that study quality,[22] prior knowledge and scientific reasoning ability are correlated to performance outcomes[23–25] and that this could be taught concurrently to current classwork. Research on corequisite and alternative courses is emerging as a possible viable solution.[26,27]In one study, chemistry students identified as under-prepared in mathematics were given 1.25 hours additional weekly instructional support as a part of their general chemistry class. Of the students who persisted, by mid-quarter no difference in scores were seen between this student group and their peers.[28] In other cases, programs with extended recitations as well as peer support and mentoring have resulted in learning gains in under-prepared student populations.[25,29–31] In cases where it was studied, these peer led supplemental instruction sessions also increased sense of belonging and emotional satisfaction scores in females in STEM.[30] One-on-one peer mentoring programs where mentors are carefully selected and trained have also shown increased learning outcomes.[32] At another university separate General Chemistry I courses were created and extra support services were given to identified at risk students.[27] In this case achievement gaps for first semester general chemistry outcomes were reduced, but after rejoining their peers in second semester general chemistry, the achievement gaps worsened.[27] In response to this emerging data on prerequisite vs supplemental instruction, Texas[33] and Tennessee[26] have both instituted widespread regulation requiring corequisite options.

In light of these studies, and based on observations of similar trends in the general chemistry courses taught at the University of California, Irvine, the department of chemistry hypothesized that offering a full concurrent enrollment course could provide the benefits of supplemental instruction, while allowing for more time on task than standard supplemental instruction programs. This expands on the previous studies on supplemental instruction and prerequisite courses to create a complete concurrent preparatory course. Rather than being peer led as many supplemental programs previously discussed, it is designed and administered by a general chemistry (GC) professor with the classroom support of graduate student teacher assistants. By giving it status as a full course, we allowed the credits to count toward the student credit load. This allotted more time on task than previously discussed supplemental instruction programs while still getting the benefits of concurrent instruction.

Our original research questions were:

1) What is the effect of implementing a concurrent preparatory course in first quarter general chemistry?

2) What are the longer term effects of the concurrent preparatory course on the following two general chemistry courses?

Course Design

The two credit supplemental instruction course met for fifty minutes on Monday, Wednesday, and Friday. The course topics generally covered a typical preparatory chemistry syllabus. Because this course was two credits, rather than three or four like most prerequisite preparatory courses, fewer topics are covered to account for the decreased credit load. By allotting course credits, we aimed to encourage greater time on topic when compared to supplemental instruction programs. Topics chosen (Table 1) focus on those needed for the first, and to a lesser extent second, quarters of the year long university level general chemistry series. This was purposely designed to encourage students to spend more time on GCA tasks than would be spent without additional course time devoted to the topics. The course schedule allowed for significant flexibility and time to review as dictated by student needs and performance. Review days were used to prepare for an exam and to review after the exam was complete. Post-exam reviews were designed to target common mistakes and more broadly to show students how to learn from formative assessments.

Before coming to class, students were asked to watch 1-3 videos totaling approximately 20 minutes. Each video covered one topic. Short, simple assignments (3-15 questions) were given on each video for accountability[34,35] and focused viewing. The problems were

Table 1: Covered Course Topics

Week	Monday	Wednesday	Friday
1	Units, Scientific Notation	Metric Conversions, Significant Figures	Dimensional Analysis
2	Subatomic particles, isotopes, atomic numbers/mass	Mols, Wavefunctions	Quantum numbers, orbitals, energy level diagrams
3	Review and Midterm Prep	Midterm 1	Review Common Midterm Issues
4	Energy and Intro to Enthalpy	Periodic Trends	Naming Ionic and Covalent
5	Naming Acids	Mass percent and empirical formula	Chemical Bonding and Lewis Structure Intro
6	Polarity	Midterm 2	Review Common Midterm Issues
7	Holiday	Balancing Reactions and mol ratios	reaction stoichiometry problem solving
8	Solution concentrations and dilutions.	Review and connect	Review and connect
9	Energy and the first law of Thermodynamics	Review Day (optional, due to holiday)	Holiday
10	Midterm 3	Review	Review

simple, generally one step, and directly correlated with the videos. They were content based allowing students to complete with book or internet use or previous knowledge. A sample of an assignment given can be found in the supplemental information. Students were given unlimited attempts and the problems were due twenty minutes before the beginning of class to allow instructor viewing of the assignment statistics.

During class, the instructor reviewed and summarized the topics in the videos (as required by students) and active learning activities were completed. Approximately 30-40 minutes of the class time was dedicated to working problems in ad hoc groups. These exercises reviewed the problem solving they were taught in the video, first giving isomorphic examples, and then variations on the problems. Learning Catalytics, an in-class response system, provided real time feedback to the instructor to allow the instructor to adjust course content to student needs. A sample of lesson slides with questions can be found in the supplemental information.

Post-lecture homework was delivered via the adaptive learning system ALEKS. This system uses a series of assessments and algorithms to adapt assignments to students' needs. Students are required to correctly answer three consecutive questions to continue to the next topic. Additionally, the program recognizes if a student is unable to complete a topic due to a prerequisite topic rather than the current topic, and it will assign a topic on the prerequisite skill as needed. Ten percent of the assignments were dropped to allow students some flexibility in assignment completion. During the first three weeks of class, these were due on Friday and Sunday. However, student feedback on the length of the assignments and the inability to receive in-person assistance on the weekends necessitated a change to this policy. Mentoring on completing the assignment before the due date was provided but was met with significant resistance. Therefore, the assignments during weeks four through nine were due three times a week on Thursday, Friday and Sunday. This made each assignment shorter and allowed for two assignments on days that coincided with in-person office hours.

The three exams were designed as formative assessments. These fifty minute exams were held on Monday of week 3, 6 and 10. Wednesday following the exams were devoted to going over common mistakes, reviewing materials from the exams, and teaching students how to use midterm exams as formative assessments in other classes regardless of course design. Additionally, one 20 minutes extra credit quiz was given in class in response to student performance on the midterm. Midterms in the student's university level GCA class were given on Wednesday of week 4 and 7, with a final exam on Sunday of week 11. Having exams in the preparatory course before the university level course allowed time to review mistakes to prevent them from occurring on the GCA exam. The concurrent course instructor did not see any GCA exams before they were administered.

Materials and Methods

Student Selection

The study occurred over two years. In both years, the study population was taken from the School of Biological Sciences program BioEASE (Enhanced Academic Success Experience Initiative). BioEASE was implemented to increase success and retention of Biological Sciences students and includes all Biological Sciences students with an incoming SAT math score below 600. The BioEASE component of the students' experience is the same across both the control and intervention student populations.

Though the chemistry department offers several paths for admittance to GCA (Table 2), BioEASE requires all students in a single year to complete the same pathway in order to remain cohorted in their science courses. During the first year of this study, no corequisite course was available, and students were placed directly into GCA. The first year BioEASE students serve as a control group.

Once the corequisite course (GC+) was available, all BioEASE students were required to take the corequisite course. The consistent selection criteria into BioEASE provided an equivalent student population to compare performance across both years to investigate the effect of the concurrent course on student performance and retention. The group of BioEASE students who took the concurrent course serve as the intervention group.

Table 2: Pathways for Entrance to General Chemistry A (GCA)

	Description	Year(s) available
1	SAT Math Reasoning test score of 600 or higher	1-2
2	ACT Math test score of 27 or higher	1-2
3	AP Chemistry exam score of 3	
4	SAT Chemistry subject exam score of 700 or higher	1-2
5	Completion of or concurrent enrollment in Calculus or Classical Physics	1-2
6	Online homework instruction module using ALEKs	1-2
7	Concurrent enrollment in General Chemistry A and General Chemistry Plus (a preparatory supplement to general Chemistry)	2

Participants and Procedures

The data were collected across 3 General Chemistry (GCA, GCB, GCC) courses during the 2018-19 and 2019-20 academic years at a research-intensive university in the western United States. Students in the 2018-19 cohort (Cohort 1) started their general chemistry courses without an additional supplemental course. Students in the 2019-20 cohort (Cohort 2) started their general chemistry courses by taking the first course in general chemistry (GCA) and a concurrent general chemistry preparatory course (GC+) during the fall quarter which served as additional supplemental instruction. When referring to the first course and the preparatory course together we will use the notation GCA+. Cohort 1 served as the control group to Cohort 2 where the concurrent enrollment in an additional preparatory course was the intervention. Students who qualified through Paths 1-5 were only used to calculate standardized final exam scores. Descriptive information of the students included in the study can be found in Table 3. This study was approved by the University of California, Irvine, Institutional Review Board as exempt (IRB 2018-4211).

Table 3: Student demographics and previous academic performance.

	Cohort 1		Cohort 2		
Parameters	SAT Math ≥ 600	Control Group	SAT Math ≥ 600	Intervention Group	Total
Female (%)	52	82	58	84	61
First-Generation (%)	41	78	43	73	48
Low Income (%)	23	50	28	58	31
PEERs (%)	28	75	25	76	35
Biological Sciences Major(%)	45	96	51	92	57
SAT Math Scores	677 (56)	514 (49)	676 (55)	502 (57)	645 (86)
SAT Reading Scores	601 (84)	541 (75)	606 (77)	526 (74)	590 (84)
SAT Writing Scores	602 (75)	515 (67)	606 (77)	507 (75)	587 (84)
Total	1078	$n_1 = 252$	1432	$n_2 = 321$	$n = 3083$

Common Final Exam Procedures

All students in general chemistry are required to take the same common final exam. This is administered on the Sunday of week 11 during a two hour block when all students take the same exam simultaneously. The exam is 50 multiple choice questions.

The same exam was given during Fall 2018 and 2019. It is instructor agnostic and the raw scores are available for comparison. We compared the common final exam scores between the Cohort 1 (Fall 2018) and Cohort 2 (Fall 2019).

Statistical Methods

GCA common final exam scores were analyzed in three parts; percent on GCA common final and standardized score on GCA common final. Linear regression models were fit to the data and analyses were performed using the open-source programming environment R [36]. The linear regression model is given by:

$$Y_{ij} = x_{ij}^t \beta + \epsilon_{ij}, \tag{1}$$

where Y_{ij} is the response of the jth student of class i (i = 1,2, j = 1,..., n_i), n_i is the size of the class i, x_{ij} is the covariate vector of the jth student of class i (whether or not the student received the intervention, standardized SAT math scores, standardized SAT reading scores, first generation status, low income status, gender, and PEER status), β is the parameter that we will be estimating, ϵ_{ij} is the random error associated with the jth student of class i, and ϵ_i is the error vector of class i. Interaction terms between the intervention and demographic characteristics were tested, but not found to be significant. The models are based on students who scored below 600 on the SAT Math section. Robustness checks were made including all students (including students who scored at least 600 on the SAT Math section) and model results can be found in the supplemental information (SI). The standardized exam score for each student in our sample represent the number of standard deviations an observation was above (or below) the average exam score for all students who took the common final in the same quarter. We compared the standardized common final exam scores for GCA for the two cohorts (the control took only GCA and the intervention that took both GCA and the concurrent enrollment course).

Qualitative Data Analysis

Due to significant pedagogy research at the university, first-year students tend to be oversurveyed. Given the main focus of this study on quantitative performance and to avoid overburdening students with additional surveys, the standard university course evaluation was used to determine students' perceptions of the course. The evaluation is delivered online during the final week of the quarter.

Qualitative data analysis is suitable for examining student perceptions, as the methodology attends to the multiple realities experienced by different students and seeks insights based on understanding meaning in the context of the course.[37] Two authors (KD and SML) conducted an inductive content analysis[38] of student responses in the course evaluation. To minimize potential bias, these two researchers were not involved with the instruction of the course.

Interrater reliability was determined based on 20% of the data coded by both researchers using joint probability of agreement and Cohen's kappa[39,40] with agreement = 96% and $\kappa = 0.76$ respectively. As the Cohen's kappa value falls within the range of substantial agreement,[41] we proceeded with one of two researchers coding the remaining items.

Results

Performance Outcomes

Table 4: Performance in general chemistry

	Cohort 1		Cohort 2		
Parameters	SAT Math ≥ 600	Control Group	SAT Math ≥ 600	Intervention Group	Total
GCA Final					
Percent	79 (14)	61 (17)	76 (13)	66 (17)	75 (15)
Standardized Score	0.29 (0.94)	-0.73 (0.93)	0.26 (0.94)	-0.40 (1.06)	0.11 (1.00)
Grade in GC					
GCA	2.82 (0.93)	2.14 (1.07)	2.87 (0.87)	1.65 (1.01)	2.67 (1.01)
GCB	2.85 (0.85)	1.86 (1.05)	2.79 (0.75)	2.16 (0.80)	2.68 (0.87)
GCC	2.69 (0.94)	1.68 (1.02)	3.06 (0.82)	2.28 (1.05)	2.75 (0.99)
Pass Rate					
GCA (%)	91	79	92	61	88
GCB (%)	94	71	96	83	92
GCC (%)	89	62	88	75	85
Persistence					
GCB (%)	83	85	87	75	84
GCC (%)	75	72	80	66	76
Total	1078	$n_1 = 252$	1432	$n_2 = 321$	$n = 3890$

Common Final

On the 50 question, multiple choice final exam in GCA, the intervention group (students who took the concurrent Chemistry supplemental course) outperformed the control group (the median score increased by 6 percent, Figure 1). Summary statistics for performance in the first general chemistry course can be found in Table 4. Relative to all students who took the first general Chemistry course (including students who took Paths 1-5), students in the intervention group performed better than students in the control group ($t = 3.99, p < 0.001$). And students in the control group performed at a significantly substandard level, while students in the intervention group performed similarly to their peers. In the control population the median z-score (calculated in comparison to all students who took GCA in the same year) was -0.81; 50% of the control students scored 0.81 standard deviations below the average GCA student. In the intervention population the median z-score was -0.09; students who took GCA and the concurrent course (GC+) typically scored the same as typical students who did not need preparatory instruction in Chemistry (i.e. SAT scores > 600). Final exam scores are not curved or subject to changes by the professor. From the linear regression model presented in Table 5, we conclude that the intervention group scored higher on the common final compared to the control group ($\hat{\beta}_1$ = 5.74, p < 0.001). This conclusion accounts for the demographic and previous academic performance differences in order to tease out the effect of the intervention.

Table 5: Linear regression model for the percent on the GCA common final. The model only includes students with SAT Math scores below 600.

Parameters	Coefficient	Standard Error	Test Statistic	p-value
Intercept	86.18	2.64	32.69	<0.001
Intervention	5.74	1.30	4.41	<0.001
Female	-3.20	1.72	-1.86	0.063
PEER	-2.72	1.55	-1.76	0.080
First Generation	1.36	1.67	0.81	0.418
Low Income	-3.49	1.39	-2.51	0.013
Standardized SAT Reading	1.43	0.72	1.99	0.048
Standardized SAT Math	13.33	1.50	8.91	<0.001

$R^2 = 0.21$

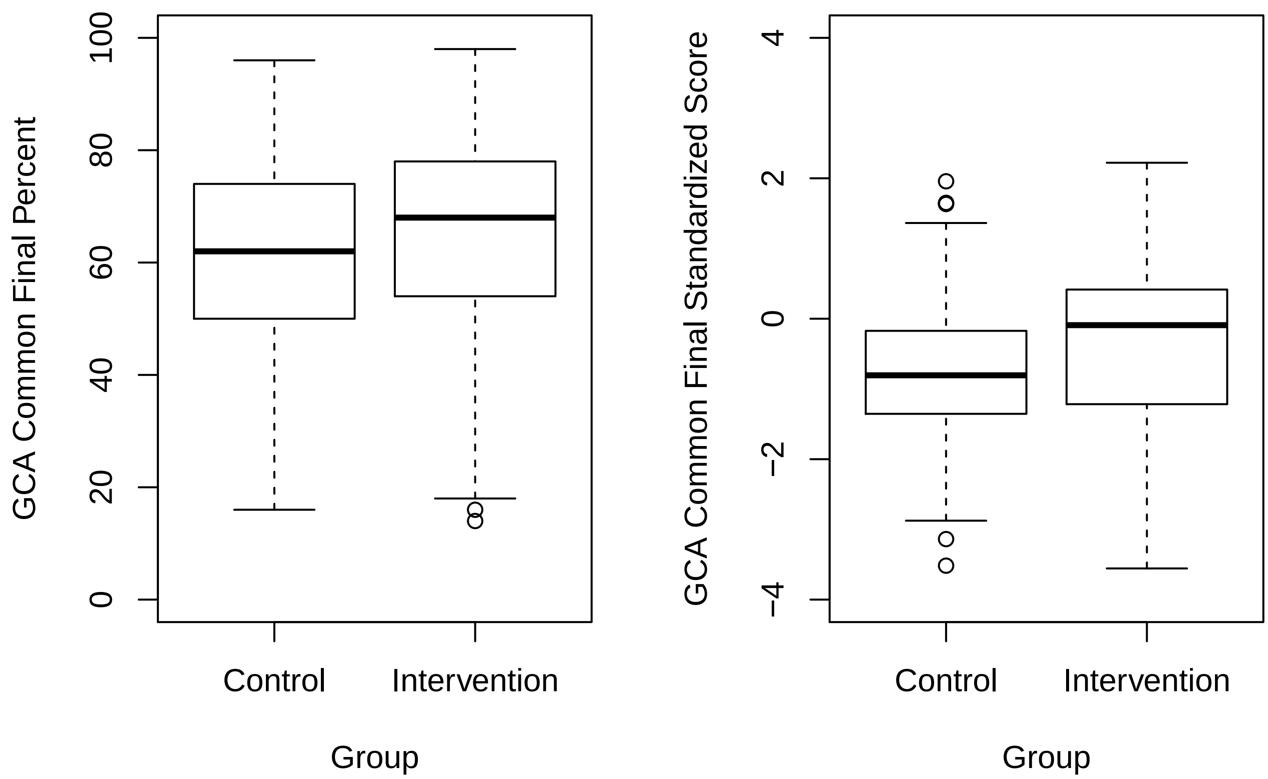


Figure 1: Performance on the final exam. The raw common final percent is on the left and the standardized final exam scores (relative to all students who took GCA in the same year) is on the right.

Grades and Retention

Students were also compared based on GCA grade and retention. Unfortunately due to a change in grading policy, although students did better on the common final (Figure 1), indicating improved learning outcomes, they were given lower course grades. The grades given in Fall 2018 (Cohort 1) (online homework module) were significantly higher (t = -5.58, $p < 0.001$) than in the Fall 2019 (Cohort 2) (see Table 4). Grading policies in GCB and GCC were consistent for both cohorts and in both GCB and GCC the intervention group received higher grades than the control group (GCB grades t = 3.37, $p < 0.001$; GCC grades t = 5.53, $p < 0.001$).

Likely due to the lower grades in GCA, we do see a higher attrition rate in the intervention group, even given the higher common final grades. However, for the students that do not quit after GCA, we do see an increase in retention for General Chemistry B (GCB) and General Chemistry C (GCC) (Tables 6 and 7.) Out of the students who went on to take GCB, a higher proportion passed out of the intervention group (Control: 71% (153/214), Intervention: 83% (200/241)). We see the same trend for GCC; out of the students who went on to take GCC, a higher proportion of the Intervention students passed the third course (Control: 62% (112/182), Intervention: 75% (158/212)).

Table 6: Contingency tables for students in the control group who took and passed the three levels of general chemistry.

GCA	Passed	Did Not Pass	Total
Total N(%)	198 (79)	54 (21)	$n_1 = 252$

GCB	Passed	Did Not Pass	Total
Took N(%)	153 (61)	61 (24)	214 (85)
Did Not TakeN(%)	0 (0)	38 (15)	38 (15)
Total N(%)	153 (61)	99 (39)	$n_1 = 252$

GCC	Passed	Did Not Pass	Total
Took N(%)	112 (44)	70 (28)	182 (72)
Did Not Take N(%)	0 (0)	70 (28)	70 (28)
Total N(%)	112 (44)	140 (56)	$n_1 = 252$

Table 7: Contingency tables for students in the intervention group who took and passed the three levels of general chemistry.

GCA	Passed	Did Not Pass	Total
Total N(%)	195 (61)	126 (39)	$n_2 = 321$

GCB	Passed	Did Not Pass	Total
Took N(%)	200 (62)	41 (13)	241 (75)
Did Not Take N(%)	0 (0)	80 (25)	80 (25)
Total N(%)	200 (62)	121 (38)	$n_2 = 321$

GCC	Passed	Did Not Pass	Total
Took N(%)	158 (49)	54 (17)	212 (66)
Did Not Take N(%)	0 (0)	109 (34)	109 (34)
Total N(%)	158 (49)	163 (51)	$n_2 = 321$

Student Perceptions

In the university course evaluation, students were asked to address the following three items: strengths of the course, potential improvements for the course, and additional comments (n = 152 students and 456 responses). About 30% of the responses were blank (n=139), with a majority of these appearing in the question for additional comments. Another 26% of the responses were excluded because they solely commented on the instructor and not the course, e.g. being accessible and enthusiastic (n=118). The remaining dataset (n=199) was inductively coded to elucidate negative and position student perceptions emerging from the university course evaluation data (Table 8).

Negative Perceptions

The most common negative perception was the high workload in the course (n=50). Because ALEKS is an adaptive program, students who cannot get three correct answers in a row on a topic are required to repeat the topic or, in some cases, go back to an earlier topic. Due to this structure, students who are already struggling will be given more homework to complete, and this can often be a point of frustration. Many students did not complete all of the homework required to get a complete homework score even though unlimited attempts are given.

The next two most common negative perceptions were the lack of complete alignment with GCA (n=41) and the perceived disorganization of the course (n=37). Because this was a preparatory course, it necessitated including foundational topics that would not be covered in the GCA course. Some students reported that the course should have been directly correlated to GCA rather than covering topics outside of GCA, perhaps without fully recognizing the need and usefulness of the foundational topics. Relatedly, the course was designed to respond to students' needs, which necessitated flexibility, and some students interpreted this flexibility as disorganization. Lectures for review days were developed based on information from surveys and exams, leading to the release of lecture material very shortly before the start of class. The originally posted schedule of topics was also revised in response to students having more difficulty in some areas than anticipated. Even though these points were discussed in the syllabus, in lecture each day for the first two weeks, and in course emails, more consistent messaging and modeling throughout the academic quarter many alleviate these student concerns in future years.

Positive Perceptions

In direct contradiction to the above, the most common positive perception was the alignment of the course to GCA (n=30). Covering foundational concepts prior to and at a more tailored pace than their GCA course assisted students in their confidence in and completion of GCA. These comments support the notion that the related negative perception can be addressed with increased communication.

The next two most common positive perceptions included the availability of practice problems (n=29) and the utility of multiple sources of explanations of GCA topics (n=20). Because the courses had different instructors, explanations of topics seen in both courses differed. Hearing multiple styles of explanation helped students who preferred the explanations in GCA+, which were designed for a lower preparation level. Similarly, students commented positively on the large number of practice problems, multiple ways to approach problems, and step-by-step guidance on problems. Due to time and topic constraints, university courses often skip problem-solving steps involving algebraic rearrangements or other foundational mathematical topics. GCA+ focused on working through those steps at a more methodical pace with explanations that the students could bring into GCA. Furthermore, some students reported that the course material provided real-world connections to chemistry topics (n=3). Overall, these positive perceptions are in contrast to a smaller number of responses that indicated the course could have provided more examples and practice problems (n=13) and a subset of the "disorganized" coded responses where students interpreted having multiple ways of solving the same problem as disorganized.

Another positive perception was on the interactive nature of the course (n=14). As described in the course design portion, students worked on problems generally together in groups. Students appreciated being given time to solve problems in class with help from the instructor. They commented that the interactive nature of the course helped them to practice and understand the material. They also appreciated that the more tailored pace of the course helped them make sense of what was being taught. Such perceptions are in contrast to a similar number of responses that indicated the course was rushed (n=13).

Table 8: Student perceptions of the course based on inductive coding of university course evaluation.

Perception	Code	Description	Frequency N (%)[a]
Negative	High Workload	There was more homework than the student expected	50 (25%)
Negative	Lacks GCA alignment	Content seen as not relevant to the GCA course	41 (21%)
Negative	Disorganized	Course was perceived to lack organization such as changes in the middle of the quarter	37 (19%)
Negative	More examples	The Course could have provided more examples and practice problems	13 (7%)
Negative	Rushed	The course moved at a pace too rapid for the student	13 (7%)
Positive	Aligns with GCA	The course content was seen as helpful in relation to the GCA course	30 (15%)
Positive	Practice Problems	There were many problems and useful step-by-step problem-solving strategies	29 (15%)
Positive	Examples	Course material was well explained using multiple examples and analogies	20 (10%)
Positive	Interactive	The student found v arious interactive classroom activities helpful in learning	14 (7%)
Positive	Real World	Course material provided real-world connections to chemistry topics	3 (2%)

[a] Frequency and the associated percentage are counted out of the total number of 199 responses analyzed. As some responses have multiple codes, the total adds up to over 100%.

Discussion

Performance Outcomes

The stated goal of the corequisite course was to increase learning and retention in the general chemistry series without causing students to fall a complete quarter behind in their course sequence as prerequisite courses cause. Increased performance on the GCA common final exam indicates that student learning outcomes in GCA were improved by inclusion of the concurrent chemistry course (GC+).

Due to external grading and societal factors (see Limitations below) confounding other measures, the best measure of the concurrent course success is the performance of students on the GCA common final. The improvement on both raw score, and in comparison to the GCA general student population (Table 4) shows a positive effect on learning outcomes of the concurrent course on GCA. This result shows that a concurrent preparatory class is a viable solution to improve student learning without causing students to fall behind that of their peers through delaying university level courses.

The lower retention in students going from GCA to GCB is most likely the result of an unrelated change in grading policy by the chemistry department. This change caused a higher rate of Ds and Fs and could also have implications for students' desire and motivation to continue. Grading policies were consistent in GCB and GCC for both cohorts and higher retention was observed supporting the viability of this approach. Though beyond the scope of this paper,[42] this result shows a need for deliberate consideration of future grading policies.

Greater retention in General Chemistry B (GCB) and General Chemistry C (GCC) was seen in the intervention student population. This is likely due to a confluence of reasons. Measured increases in learning outcomes for GCA can have down stream effects on courses which also use this material. Additionally, performance in concurrent enrollment course could cause a self-elimination process after GCA, lowering retention after GCA, though improving it after GCB and GCC. Coverage of GCB topics in the concurrent course may have improved learning outcomes for GCB material. Unfortunately, a high opt-out percentage for GCB final exam did not allow this to be measured directly. Increased leniency in final letter grade curving could have also increased retention. This is discussed further in the limitations section.

Student Perceptions

Variation theory describes the discrepancy between what an instructor intends to accomplish in a curriculum and what individual students may take away from the same in-class activities.[43,44] In some instances, students in a course with interactive elements under-predict their academic performance in relation to their actual grade outcomes.[45] Students perceptions of the GCA+ course should be interpreted within this literature framework and existing evidence.

The positive comments centering around alignment with GCA, practice problems, alternate explanations, interactivity of the course, and real-world connections indicate the general course structure was successful. All positive perceptions were strongly related to elements of the class that will be maintained and even improved on in future course offerings.

Elements perceived by students as negative can be addressed through modifications of the course structure and improved communication. Many students did not complete all of the online homework, showing that a reduction of less important assignments could result in more targeted homework completion. Because so many students did not complete all topics during the initial course offering, we do not expect the reduction to impact learning outcomes negatively. It is anticipated that this reduction in homework will result in less frustration and will encourage students to have a higher completion rate on the assignments identified as most important.

Perceived problems in GCA+'s alignment with GCA can be addressed through specific and detailed communication efforts. Each session the GCA+ course will state the day the topic will be covered in GCA, or what day of their GCA class will require that skill. This will reassure the students that the instructors are scheduling and planning together.

Courses designed to adapt to students necessitate flexibility and often delivery of content immediately prior to the class starting. Each time the course is taught, the instructor gains insight into what is most likely required. The expected result is tighter adherence to the originally posted schedule and a more seamless and expedient delivery of lecture content increasing course quality and student satisfaction. There is also a wealth of literature on student misconceptions in undergraduate chemistry that can be used as additional guidance on how to anticipate student struggles.[46–51]

Although students had certain negative perceptions about the course, these in fact point to areas for improvement in future course offerings. Additionally, these negative perceptions do not interfere with other parts of the course that students commonly perceived positively and are also balanced by a larger proportion of students who reported opposite ideas as positive perceptions. This offers an opportunity for greater student buy-in that should ultimately improve outcomes as the course improves.[52]

Limitations

Due to a changes in department grading policy, course grades and longitudinal retention measures were significantly confounded and should not be used as primary measures of course success. Rather than curving the section of GCA separately it was combined with another section of the course taught by the same instructor. In previous years, curving the section individually had led to students in the BioEase section achieving a higher grade for poorer performance simply because of the student population. By curving with other sections, this problem was removed, but resulted in lower final grades than the previous year. While this certainly highlights many of the issues surrounding curved grading methods, a full discussion of that goes beyond the scope of the paper.[42] Importantly, the raw common final exam scores for GCA are not subject to change based on these grading policies and are therefore the best measure of course success.

Longitudinal follow up data on retention in GCB and GCC were confounded by the COVID-19 pandemic shutdowns and Black Lives Matter social unrest that occurred in week 10 of the GCB and GCC quarters respectively. Due to severe disruptions, the final exam was made optional in GCB and GCC. This likely affected retention post GCB. Due to the high percentage of students opting out of taking the GCB and GCC common finals, these results could not be analyzed.

Conclusion

A concurrent enrollment preparatory course improved student learning outcomes as measured by a 50 question multiple choice final, in a first quarter general chemistry course sequence. Over the course of the full sequence, retention also improved, though future studies will be required to ensure that this was the result of the concurrent preparatory course rather than external factors which may have confounded the analysis. Student feedback from the initial course established areas where the course can be developed for greater improvement in outcomes in future iterations. Concurrent preparatory instruction ensured students were adequately supported with background skills and knowledge without falling behind in the course sequence as prerequisite course would necessitate.

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Supporting Information Available

The following files are available free of charge.

- Example Pre Class Assignment Questions (.Docx)
- Pictures of Example Slides for one Class (.Docx)
- Linear regression module for the percent on the GCA common Final (.PDF)

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