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## Predictors of Student Success in College-Level General Chemistry

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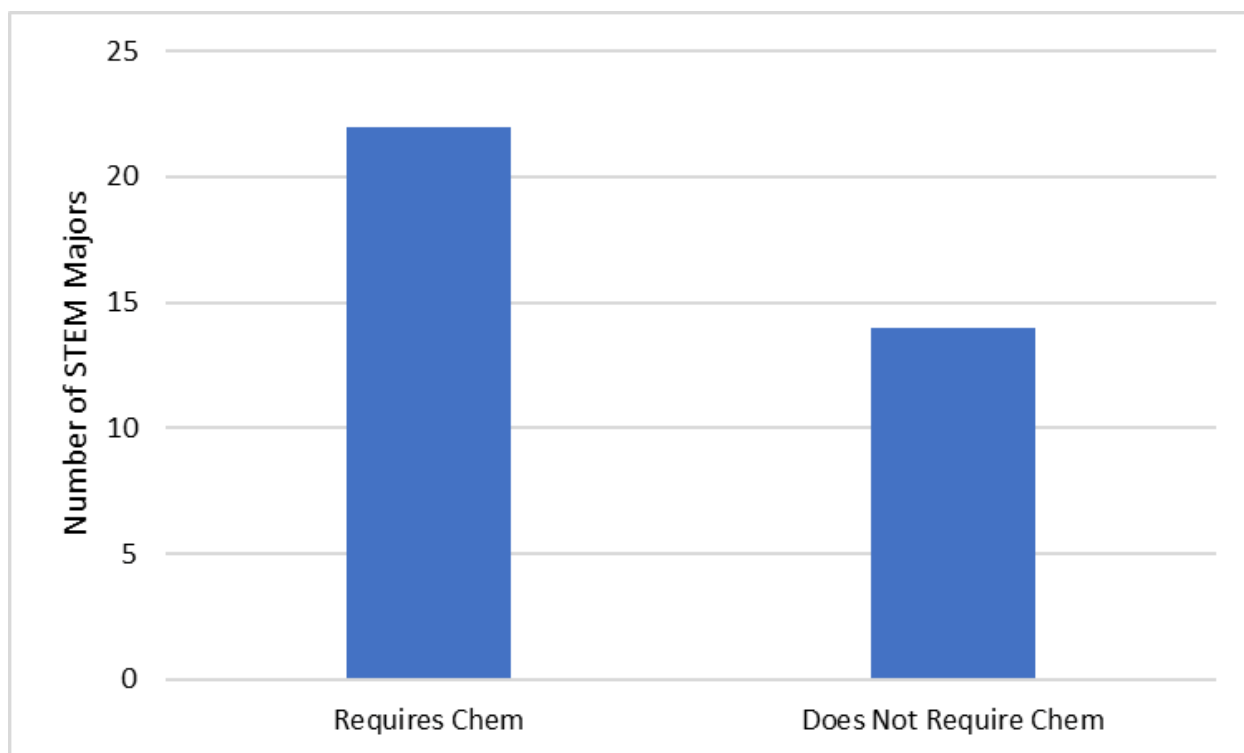
## Predictors of Student Success in College-Level General Chemistry

### Cover Page Footnote

The authors would like to thank the Department of Chemistry and General Chemistry Instructional Team at Binghamton University. The authors would also like to thank the Center for Learning and Teaching for continued support of the available chemistry resources.

## Introduction

Student success in general chemistry is an important topic at the forefront of chemistry education research. An initial question to ask is how to best define student success. There are multiple ways to define success, including student grades, career outcomes, and persistence.<sup>1</sup> A common metric of student success is a student's final grade, as this theoretically captures each student's exam performances, in-class participation, and overall mastery of the subject. However, final grade does not account for the individual differences in student expectations and aptitude for chemistry. The topic of student success in general chemistry is important to study because general chemistry is a required course for many STEM majors, including chemistry, biochemistry, biology, physics, engineering, and more at Binghamton University. Figure 1 below depicts the number of STEM majors at Binghamton University that do and do not require general chemistry as part of their major requirements. 61% of STEM majors require students to take general chemistry and the 39% of STEM majors that do not require it will often accept general chemistry as science elective credit. Student success in gateway courses such as general chemistry are linked to retention in STEM, so ensuring that students are successful in general chemistry is an important topic for maintaining students in all STEM fields.<sup>2</sup>



**Figure 1: Number of STEM Majors at Binghamton University that Require General Chemistry.** Of the 36 NYS STEM Incentive Program eligible majors at Binghamton University, 22 require completion of a general chemistry sequence, while 14 do not require it, but many accept general chemistry as a science elective that can be used for major credit, according to each department's website.<sup>3,4</sup>

Previous studies on student success in chemistry have found correlations between high school chemistry pedagogical techniques and college general chemistry success.<sup>5</sup> Additionally, a student's sense of belonging also has been found to be a strong predictor of their grade and attrition in general chemistry.<sup>6</sup> Furthermore, on a student-level, students who reported using active study habits have also been found to achieve higher grades than their peers who reported using passive study habits.<sup>7</sup> Chemical education literature has also explored the relationship between in-class group work and student success. It has been found that the implementation of small group work problem solving sessions during recitation or discussion sessions in general chemistry is associated with higher exam grades and positive student feedback.<sup>8</sup> This study looks primarily at the correlation between student final grade and student

selection of adjectives from a word bank, feeling on how group work relates to learning, and reported usage of class resources.

## **Methods**

All data used in this study is from surveys sent out to students in “CHEM 104 – General Chemistry I” and “CHEM 111 – General Chemistry Principles” from the Fall of 2022 at Binghamton University as preliminary study. CHEM 104 is the first of a three course general chemistry sequence and a lecture-based class, while CHEM 111 is a one course general chemistry sequence that encompasses lecture and lab-based activities. 877 students finished CHEM 104 and 335 students finished CHEM 111 in the Fall of 2022. Students in both classes were sent surveys in the beginning, middle, and end of the semester and survey participation is voluntary, although a certain percentage of students must fill out the survey for all students to receive extra credit. This study was approved by the Institutional Review Board as study #00004554.

The initial survey was sent out to the students on August 25, 2022, after they took the Assessment of Background Chemistry (ABC) pre-test but before they had any unit assessments. The survey asked students which section of general chemistry they were in, how much time during the week they expect to spend preparing for quizzes, learning assessments and exams in general chemistry, their major, level of their chemistry background, if they took CHEM 100 or the Chemistry Summer Workshop at Binghamton University prior to the semester, what letter grade they expect to get in this course, which resources they plan to use, their opinion on if group work helps them learn, selection of adjectives from a word bank, and general opinion on their knowledge of certain chemistry topics before taking the class. 1029 students out of 1212 answered some or all of the questions in the beginning of semester survey, for a response rate of 84.9%.

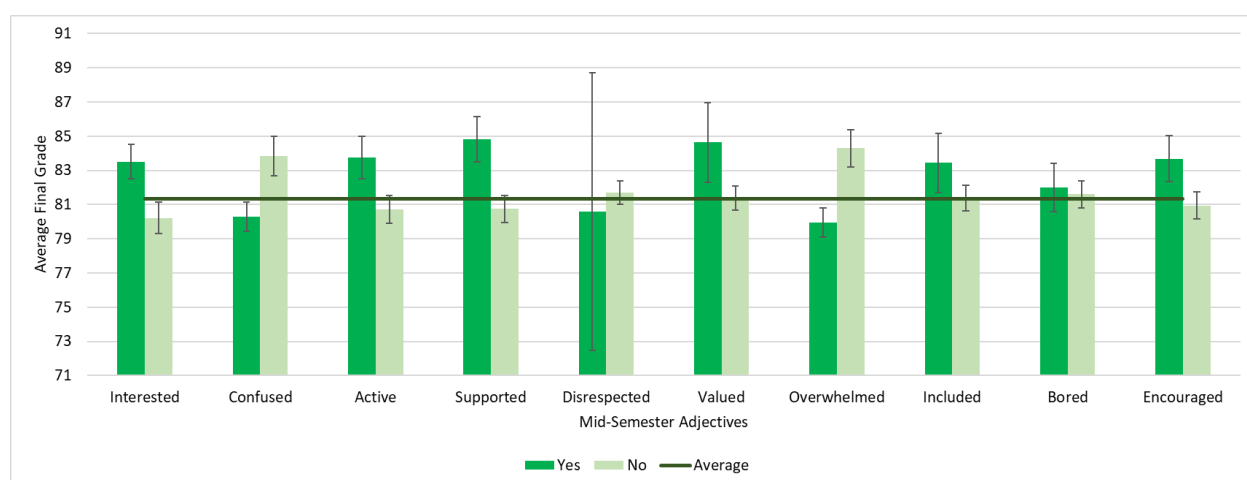
The mid semester survey was sent out to the students on October 28, 2022, after they took the first two unit assessments. The survey asked students which section of general chemistry they were in, their major, level of their chemistry background, if they took CHEM 100 or the Chemistry Summer Workshop at Binghamton University prior to the semester, how much time during the week they spend preparing for quizzes, learning assessments and exams in general chemistry, what letter grade they expect to get in this course at the halfway point of the semester, their resource usage, their opinion on if group work helps them learn, selection of adjectives from a word bank, and general opinion on their knowledge of certain chemistry topics before taking the class. 1074 students out of 1212 answered some or all of the questions in the middle of semester survey, for a response rate of 88.6%.

The end of semester survey was sent out to the students on December 8, 2022, after they took all of the unit assessments, but before they took the final exam. The survey asked students which section of general chemistry they were in, how much time during the week they spend preparing for quizzes, learning assessments and exams in general chemistry, what letter grade they expect to get in this course at the end of the semester, their resource usage, their opinion on if group work helps them learn, selection of adjectives from a word bank, and general opinion on their knowledge of certain chemistry topics before taking the class. 1031 students out of 1212 answered some or all of the questions in the end of semester survey, for a response rate of 85.1%.

## **Results and Discussion**

Based on the results of the beginning, middle, and end of semester surveys along with the student final grades, there are several preliminary factors that correlate with student success in general chemistry. One of the questions featured in all three surveys is a bank of adjectives that includes the words interested, confused, active, supported, disrespected, valued, overwhelmed, included, bored, and

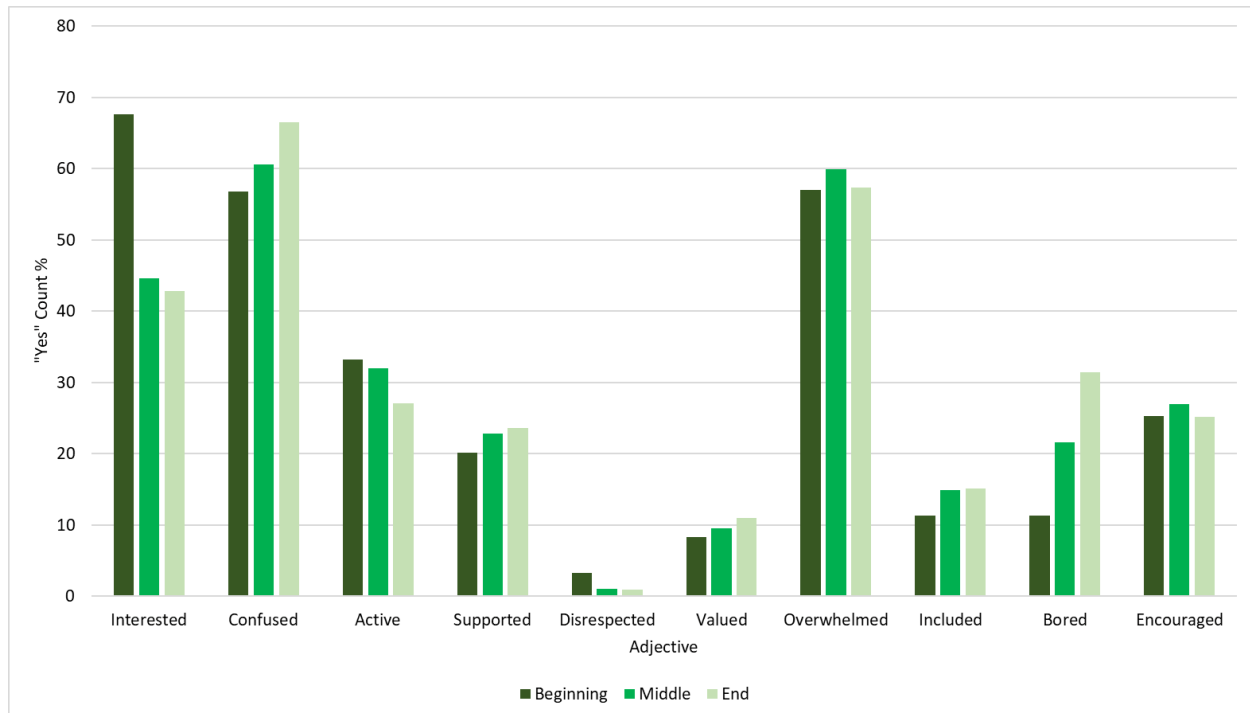
encouraged. Students are able to choose anywhere from one to eight of the adjectives and were specifically asked to pick the adjectives that best answered the prompt “When I am in class, I often feel...” for themselves. Figure 2 below demonstrates the average final grade for students who selected and did not select each adjective at the middle of semester survey. In general, students who selected more positive adjectives had average final grades. Students who selected interested, active, supported, valued, and encouraged did significantly better than students who did not at the 95% significance level. Students who selected confused and overwhelmed did significantly worse than students who did not at the 95% significance level. The differences between students who selected and did not select disrespected, included, and bored were not significantly different at the 95% significance level.



**Figure 2: Average Final Grade Compared to Reported Mid-Semester Adjectives.** Students selected as many adjectives as they wanted from a bank of eight adjectives. This data is from the mid-semester survey, where 939 total students from CHEM 104 and CHEM 111 from the Fall of 2022 responded to this question. Students who started the survey but did not answer this question were removed. The error bars represent the 95% confidence interval for the true mean final grade (z-test).

Furthermore, the proportion of students who selected each adjective changed over the course of the semester. Figure 3 plots the percentage of students who selected each adjective at the beginning, middle, and end of the semester. In general, the more positive adjectives tended to have lower percentages of students selecting them as the semester progressed, while the negative adjectives had an

uptick of students selecting them. The adjectives that decreased by more than five percent of the class over the course of the semester were interested and active. On the other hand, the proportion of students who selected confused and bored did increase by over five percent of the class from the beginning to the end of the semester. The rest of the adjectives stayed relatively the same over the course of the semester.

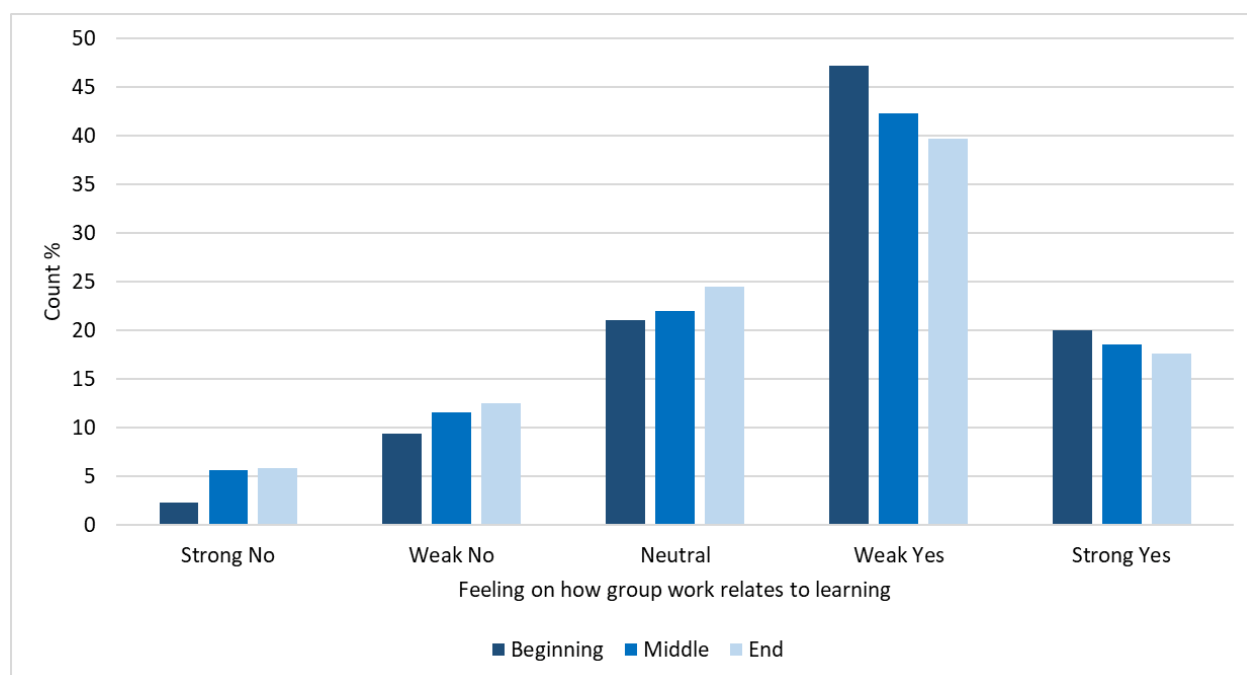


**Figure 3: Percentage of Students Selecting Adjectives Throughout Semester.** Students selected as many adjectives as they wanted from a bank of eight adjectives. This data is from the beginning, mid, and end of semester survey, where 1025, 939, and 1051 total students, respectively, from CHEM 104 and CHEM 111 from the Fall of 2022 responded to this question.

Additionally, students' perception of how group work relates to learning also changed over the course of the semester. During the beginning, middle, and end of semester survey, students were asked about their opinion of how group work relates to learning. They were able to select that it either makes learning a lot more difficult, a little more difficult, it neither helps nor hurts learning, it makes learning a little easier, or it makes learning a lot easier. Figure 4 plots the percentage of students who selected each



choice at the beginning, middle, and end of the semester. At the beginning of the semester, roughly 67% of students had a positive opinion on group work and learning, while less than 13% had an expressly negative opinion on group work relating to learning. By the end of the semester, about 57% of students had a positive opinion and 18% had a negative opinion on how group work relates to learning.

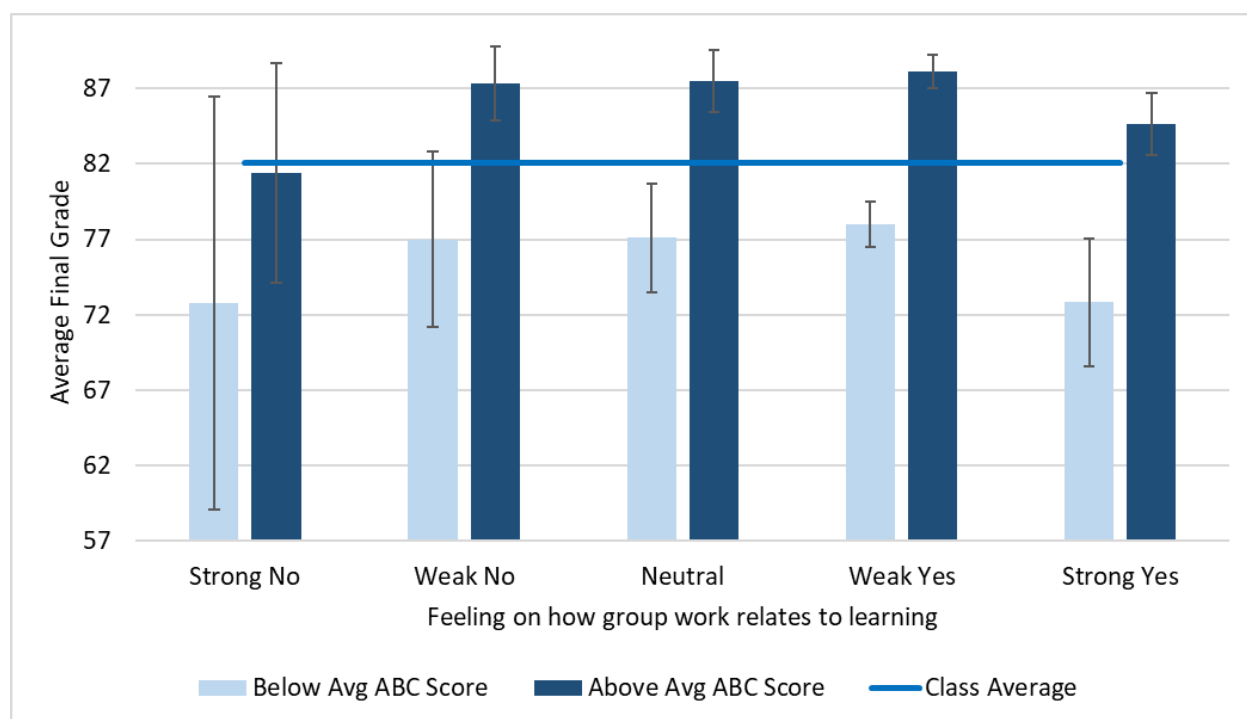


**Figure 4: Student Opinion on How Group Work Relates to Learning Over the Course of the Semester.** Students were surveyed on their opinion on how group work relates to learning and could select that group work makes learning a lot more difficult, a little more difficult, it neither helps nor hurts learning, makes learning a little easier, or makes learning a lot easier. This data is from the beginning, mid, and end of semester survey, where 1025, 1015, and 1051 total students, respectively, from CHEM 104 and CHEM 111 from the Fall of 2022 responded to this question.

To continue, there was minimal variance between students' final grade when correlated with their opinion on how group work relates to learning. Figure 5 demonstrates the relationship between the average final grade of students against their opinion with respect to group work and divides students into those who did above and below average on the ABC pre-test. The average ABC score was 57.99 out of 100. Students who did above average on the pre-test did significantly better at the 95% significance level than those who did below average on the pre-test for every answer except for students who had a

strong negative opinion on how group work relates to learning. However, the differences within the above average and below average pre-test score groups were not significant, which suggests that a student's opinion on how group work relates to learning is not a good predictor of their success.

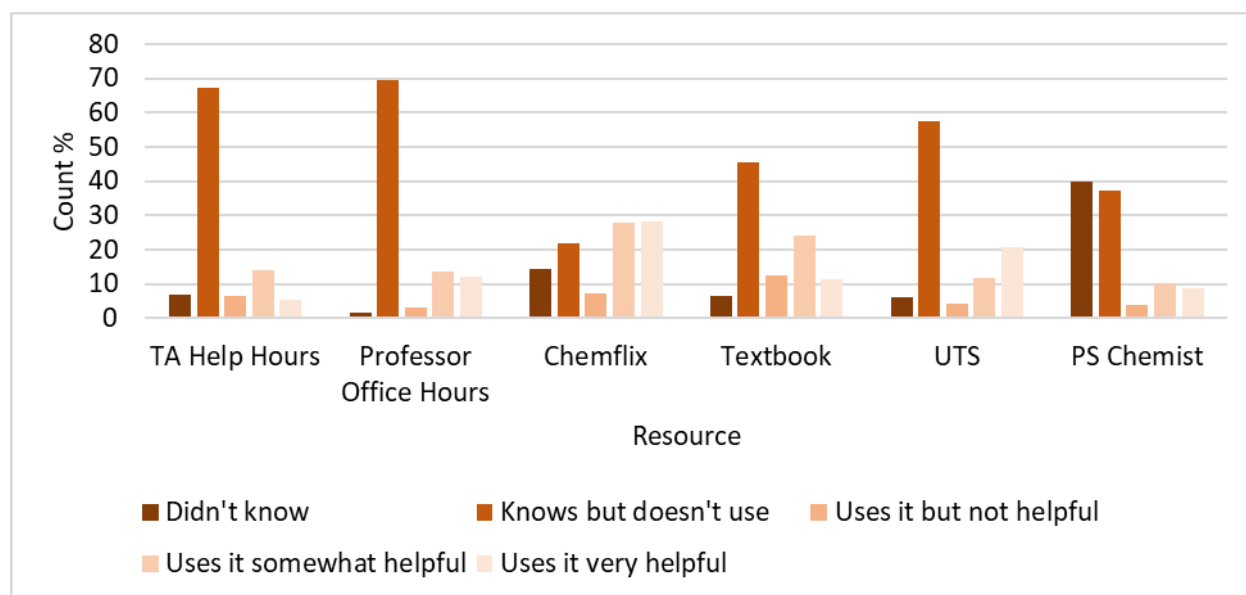
Generally speaking, students who had a neutral opinion on how group work relates to learning tended to do better than students who had an extreme opinion in either direction, but these differences were not significant at the 95% significance level.



**Figure 5: Average Final Grade Compared to Opinion on How Group Work Relates to Learning.** Students were surveyed on their opinion on how group work relates to learning and could select that group work makes learning a lot more difficult, a little more difficult, it neither helps nor hurts learning, makes learning a little easier, or makes learning a lot easier. This data is from the beginning of semester survey, where 761 students from CHEM 104 from the Fall of 2022 responded. The error bars represent the 95% confidence interval for the true proportion of students who fall into each category (z-test).

Students were also surveyed on their resource use. Figure 6 examines the percentage of students who were using each resource at the middle of the semester. Students were asked about the resources of teaching assistant (TA) help hours, professor office hours, Chemflix, textbook, University

Tutorial Services (UTS), and PS Chemist. Chemflix is a resource where an instructor runs a live practice problem session and then posts the video for all students to access at their convenience and the video library dates back to the fall of 2016. PS Chemist refers to practice problem help hours run by undergraduate TAs. Students were able to select that they did not know about the resource until taking the survey, they know about the resource but do not use it, use the resource and do not find it helpful, use it and find it somewhat helpful, or use the resource and find it very helpful. For every resource besides chemflix and PS chemist, the plurality of students knew about the resource but chose not to use it. For Chemflix, over 60% of students reported that they used the resource, the most of any resource. One potential explanation for this is that Chemflix can be accessed online, so students can use the resource at any time and location that is most convenient for them. For PS chemist, the plurality of students did not know about the resource and less than 23% of students reported using the resource, the least of any resource.

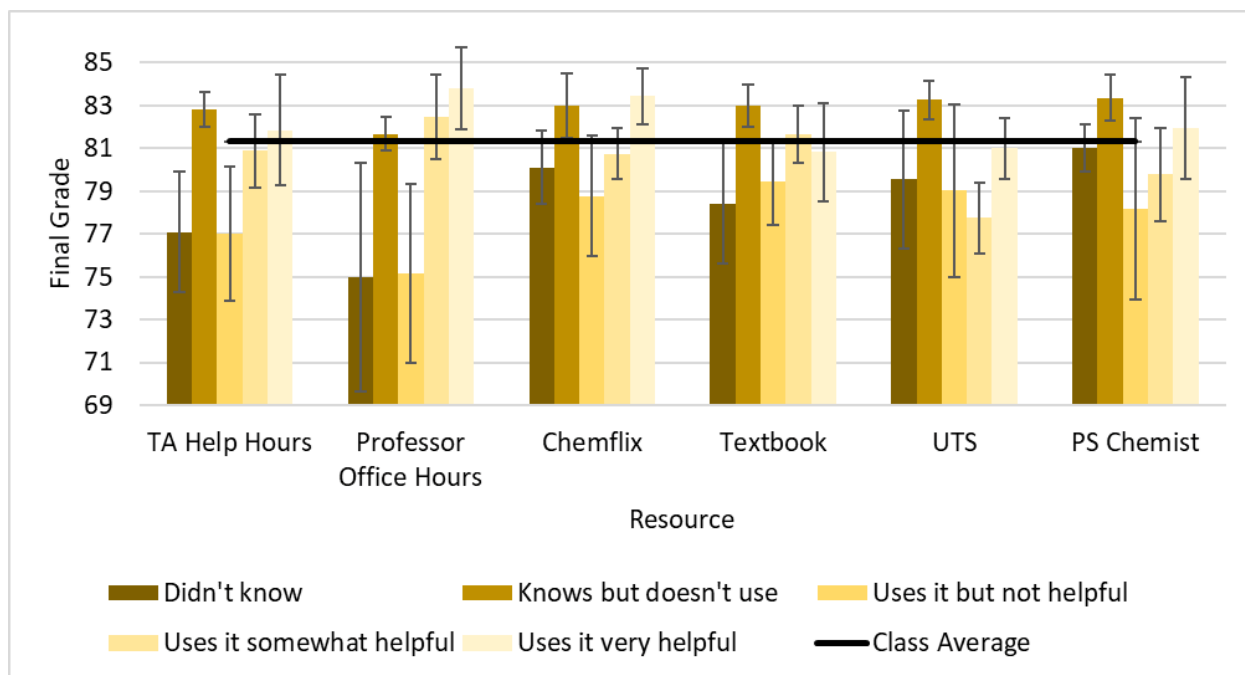


**Figure 6: Percentage of Resource Use by Students at the Middle of the Semester.** Students were surveyed on their resource use with regard to TA Help Hours, Professor Office Hours, Chemflix, Textbook, University Tutorial Services (UTS), and PS Chemist and could select that they did not know about the resource, knew about the resource but did not use it, use the resource but do not find it helpful, use the resource and find it somewhat helpful, or use the

resource and find it very helpful. This data is from the middle of semester survey, where 1070 students for each resource from CHEM 104 and CHEM 111 from the Fall of 2022 responded.

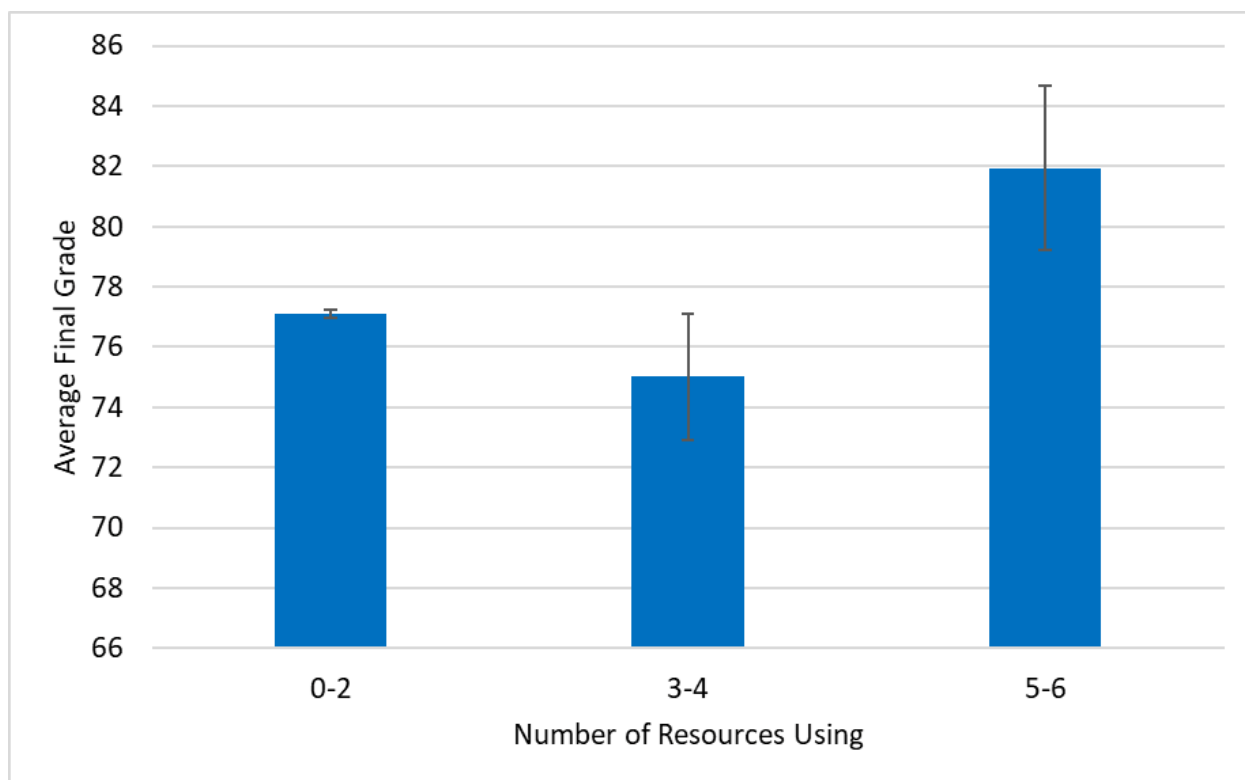
The relationship between specific resource use and final grade of the student was also explored. Figure 7 documents the average final grade of students for each category of resource use for each individual resource. Generally, for each resource, the students who either knew about the resource but

chose not to use it or used the resource and found it very helpful had the highest average final grade. On the flip side, students tended to have lower final grades when they either did not know about a resource or used the resource but did not find it helpful. However, most of the differences within each resource are not significant at the 95% level. Specifically looking at professor office hours, the students who either knew about the resource but did not use it or used the resource and found it at least somewhat helpful did significantly better at the 95% significance level than students who either did not know about the resource or used the resource but did not find it helpful. This pattern suggests that the resources offered by the general chemistry team at Binghamton University are beneficial to students as those who find them useful tend to do well in the course. Furthermore, when looking at Figure 5 as well, very few students are using resources and finding them not helpful, which suggests that students are satisfied with the resources provided.



**Figure 7: Average Final Grade Compared to Resource Use at the Middle of the Semester.** Students were surveyed on their resource use. This data is from the middle of semester survey, where 1070 students from CHEM 104 and CHEM 111 from the Fall of 2022 responded to this question. The error bars represent the 95% confidence interval for the true final grade of students who fall into each category (z-test).

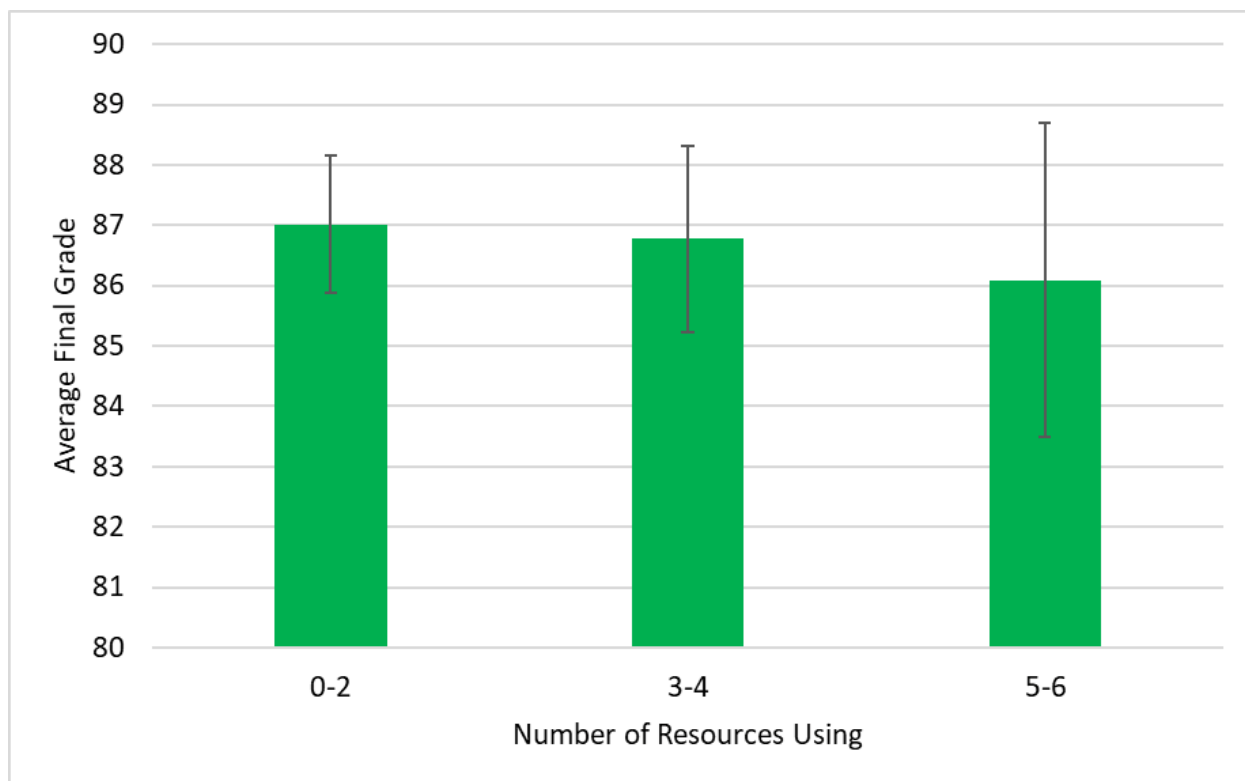
When looking at the overall number of resources students use compared to their final grade, there is not a direct correlation between the number of resources used by a student and their final grade. Figure 8 plots the average final grade of students who scored below average on the pre-test against the number of resources they reported using at the middle of the semester. While there is not a significant difference between the average final grade of students using 0-2 and 3-4 resources, the students who used 5-6 resources did significantly better than the 0-2 and 3-4 resource groups at the 95% significance level. This further suggests that the resources provided to general chemistry students are helpful as students who start the class with a weaker chemistry background perform better in the class when they take full advantage of the resources available. Furthermore, the students in the 5-6 resource category who scored below average in the pre-test ended with an average final grade that was higher than the overall average final grade for the course. This suggests that students who do below average on the pre-test should consider using most or all of the resources provided to them throughout the semester to be successful in general chemistry.



**Figure 8: Average Final Grade Compared to Number of Resource Using in Below Average Pre-Test Students at Middle of Semester.** Students were surveyed on their resource use with regard to TA Help Hours, Professor Office Hours, Chemflix, Textbook, University Tutorial Services (UTS), and PS Chemist and could select that they did not know about the resource, knew about the resource but did not use it, use the resource but do not find it helpful, use the resource and find it somewhat helpful, or use the resource and find it very helpful. This data is from the middle of semester survey, where 826 students from CHEM 104 from the Fall of 2022 responded, where 405 of those students scored below average on the pre-test. The error bars represent the 95% confidence interval for the true final grade of students who fall into each category (z-test).

While students performed below average on the pre-test and used 5-6 resources did significantly better than their counterparts who used less than 5 resources, the same trend does not exist in students who scored above average on the pre-test. Figure 9 plots the average final grade against the number of resources above average pre-test students reported using at the middle of semester. The trend goes the opposite direction, where students who reported using 0-2 resources did slightly better than those who reported 3-4 resources and likewise 5-6 resources, but the differences between each group were not statistically significant at the 95% confidence level and thus it is likely that the differences in average final

grades are due to random chance. This graph suggests that for students who score above average on the pre-test, the number of resources that they use has no direct correlation to their final grade in the class.

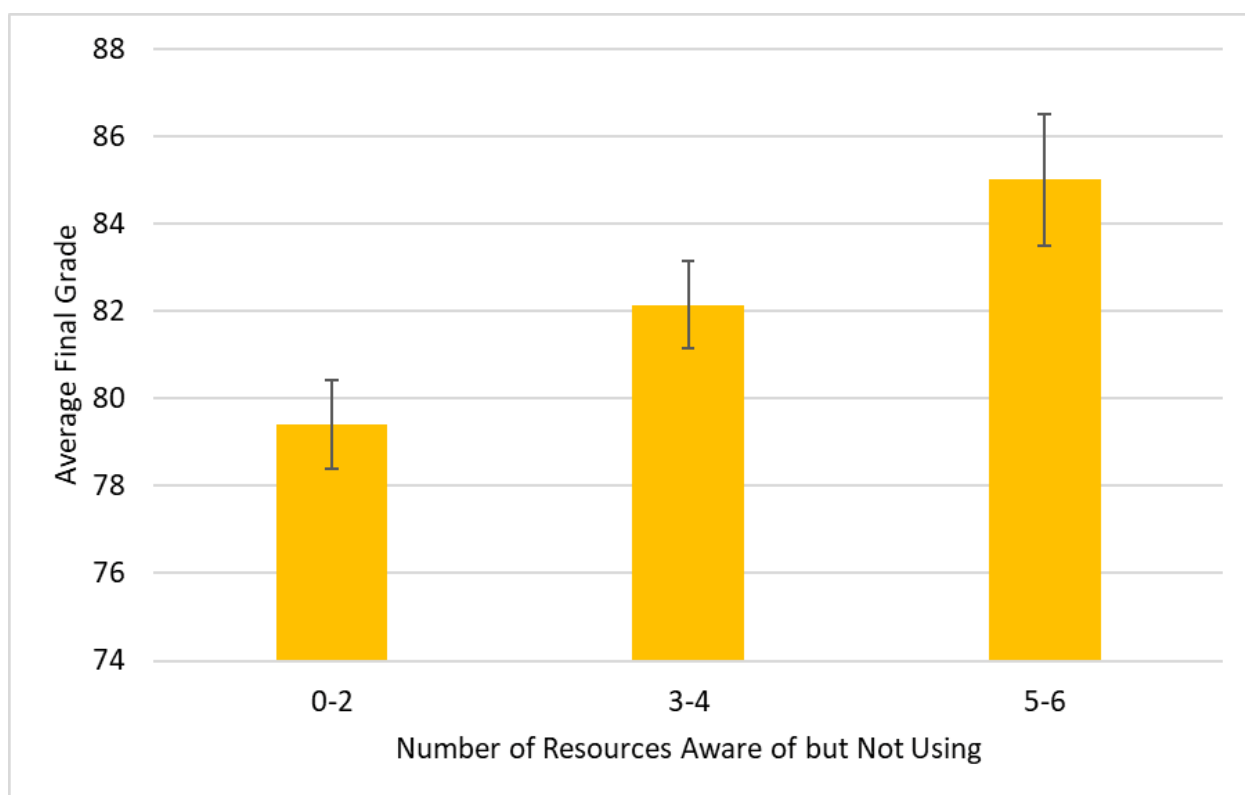


**Figure 9: Average Final Grade Compared to Number of Resource Using in Above Average Pre-Test Students at Middle of Semester.** Students were surveyed on their resource use with regard to TA Help Hours, Professor Office Hours, Chemflix, Textbook, University Tutorial Services (UTS), and PS Chemist and could select that they did not know about the resource, knew about the resource but did not use it, use the resource but do not find it helpful, use the resource and find it somewhat helpful, or use the resource and find it very helpful. This data is from the middle of semester survey, where 826 students from CHEM 104 from the Fall of 2022 responded, where 421 of those students scored above average on the pre-test. The error bars represent the 95% confidence interval for the true final grade of students who fall into each category (z-test).

The relationship between the number of resources a student is aware of but not using and their final grade was also explored. Figure 10 plots the average final grade of students in the categories of those who knew about 0-2 resources they were not using, those who knew about 3-4 resources they were not using, and those who knew about 5-6 resources they were not using. As the number of resources students are aware of but not using increases, their average final grade also significantly



increases at the 95% confidence level. Table 1 illustrates that the average ABC pre-test score of students also increases as the number of resources they are aware of but not using increases. This trend suggests that the highest performing students are aware of all the resources, but actively choose not to use them, while the lowest performing students either are not aware of the resources or are using almost all of them. Furthermore, this trend exists at both the start and end of the semester with regard to pre-test and final grades, respectively.



**Figure 10: Average Final Grade Compared to Number of Resources Student is Aware of but Not Using at Middle of Semester.** Students were surveyed on their resource use with regard to TA Help Hours, Professor Office Hours, Chemflix, Textbook, University Tutorial Services (UTS), and PS Chemist and could select that they did not know about the resource, knew about the resource but did not use it, use the resource but do not find it helpful, use the resource and find it somewhat helpful, or use the resource and find it very helpful. This data is from the middle of semester survey, where 1070 students from CHEM 104 and CHEM 111 from the Fall of 2022 responded. The error bars represent the 95% confidence interval for the true final grade of students who fall into each category (z-test).

**Table 1: The Number of Resources a Student is Aware of but Not Using Compared to Their Average Pre-Test Score.** Students were surveyed on their resource use with regard to six different course resources and had the

option to select that they knew about the resource but did not use it. This data is from the middle of semester survey, where 1070 students from CHEM 104 and CHEM 111 from the Fall of 2022 responded.

Number of Resources Aware of but Not Using	Avg ABC Score
0-2	57.29
3-4	59.59
5-6	63.75

There are some potential sources of error with this data set and method of data collection. First, there is likely some nonresponse bias as not all students answer the survey. Research indicates that there is risk of nonresponse bias and polarization of opinions in online surveys of college students.<sup>9</sup> For CHEM 104 and CHEM 111 in the Fall 2022 semester, 89.0% of students at least started the initial survey, 88.9% of 1212 students at least started the mid semester survey, and 85.1% of students at least started the final survey. Students who answer surveys are perhaps more likely to have other confounding traits. For instance, students who answer surveys may be more likely to be interested in the course than those who do not and thus the recorded percentage of students interested in the course is higher than the true value for all students.

Another potential source of error is that students do not accurately report true answers while filling out the survey. Students may simply just click random entries to fill out the survey as quickly as possible without regard for what they are selecting. Furthermore, this source of error is difficult to detect as there is no perfectly accurate method for discerning carelessly invalid survey responses from valid ones.<sup>10</sup> A third source of error that may have impacted the data is that several assumptions were made for the statistical analysis. It was assumed that all of the data followed a normal distribution and that all of the recorded data is independent of each other, which cannot be guaranteed. Similarly, the sample of

students surveyed was not a random sample and thus any conclusions cannot be generalized beyond general chemistry students at Binghamton University who answer surveys.

This research is important to the field of chemical education because it is important for educators and students alike to understand the factors that support student success in general chemistry. As general chemistry is a required course for many majors outside of chemistry and a gateway course for many STEM majors, it is important that students are successful in general chemistry to retain them in STEM.<sup>2</sup> Further research could explore other factors that may correlate with student success in general chemistry, such as sense of belonging, perceived difficulty of chemistry, and number of credits a student is taking that semester. Future work could also explore different metrics to measure student success in general chemistry that go beyond final grade. For instance, student success could also be measured by subtracting a student's expected final grade at the beginning of the semester from their true final grade or by measuring their satisfaction with the course after completion.

### **Conclusion and Future Work**

Students who selected certain adjectives had higher average final grades than students who did not select those adjectives. Students who selected "interested," "active," "supported," "valued," or "encouraged" tended to do better in the class than students who did not select those adjectives, while those who selected "confused" and "overwhelmed" tended to do worse than their peers who did not select those adjectives. As the semester progressed, students selected the adjectives of "interested" and "active" less, while they more often selected the adjectives of "confused," "supported," "valued," "Included," and "bored."

Student opinion on how group work relates to learning trended more negative over the course of the semester, as less students selected a positive association between group work and learning as the

semester progressed, while more students selected a neutral or negative association. In general, students who had neutral feelings on how group work relates to learning tended to do better in the course than those who had strong feelings, even when accounting for pre-test scores.

For most resources, the plurality of students knew about the resource but did not use it. Students tended to have a higher final grade when they knew about a resource and did not use or used the resource and found it at least somewhat helpful, as opposed to students who did not know about the resource or used it but did not find it helpful. This suggests that general chemistry at Binghamton University could be improved by more effectively communicating to students about all the resources available to them and that they should try various resources until they find the best one for their specific learning needs. The final grade of students with below average pre-test scores significantly increases the more resources they use, while there is no significant trend in either direction for students who scored above average on the pre-test. There is a positive correlation between the number of resources a student is aware of but not using and their final grade, as students tended to do better the more resources, they knew about but did not use.

Future research may focus on different methods to quantify student success. Alternative measurements of student success include the difference between a student's expected grade at the start of the semester and their final grade. In this system, a negative value indicates the student did worse than expected and a positive value indicates that the student did better than expected. This metric accounts for the student's individual expectations and background in chemistry. This value is potentially more indicative of student success than just the final grade because the context of the student's goals in the class are lost with that metric. For this study, final grade is used as the sole measure of student success, but future studies will use the new metric as students are now asked about their expected final grade in their beginning of semester survey, as of the Fall 2023 semester.

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